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WADC TECHNICAL REPORT 56-585
PART I
ASTIA DOCUMENT No. AD 142007

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EFFECTS OF TEMPERATURE-TIME-STRESS HISTORIES ON THE MECHANICAL PROPERTIES OF AIRCRAFT STRUCTURAL METALLIC MATERIALS

Part I. Temperature-Time Studies for 2024-T3 and 7075-T6 Alclad Sheet

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NORTHROP AIRCRAFT, INC.
HAWTHORNE, CALIFORNIA

SEPTEMBER 1957

WRIGHT AIR DEVELOPMENT CENTER

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MATERIALS LABORATORY
CONTRACT No. AF 33(616)-3028
PROJECT No. 7360

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Carpenter Litho & Prtg. Co., Springfield, O
[illegible] – November [illegible]

FOREWORD

This report was prepared by Northrop Aircraft, Inc. under WADC Contract No. AF33(616)-3028. The contract was initiated under Project No. 7360, "Materials Analysis and Evaluation Techniques", Task No. 73605, "Design Data for Metals". The work was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. R. F. Klinger acting as project engineer.

This report covers work conducted from June 1955 to December 1956.

The authors acknowledge the assistance of personnel of Northrop's Engineering Metallurgical Laboratory in performance of exposure, tensile and hardness tests, Mr. A. Scow in data reduction and report preparation and Mr. T. Osa in data analysis.

This report was published by Northrop Aircraft, Inc. as Report No. NAI-57-679.

ABSTRACT

In order to establish realistic design criteria applicable to aerodynamically heated materials and their complex combinations of temperature, time and stress exposure and inspection criteria for materials after exposure to complex service conditions, the tensile properties of 2024-T3 alclad and 7075-T6 alclad sheet were determined at room temperature, 200, 300 and 400°F after single and sequential multiple exposure in the range 250 through 600°F. In addition, the Rockwell hardness properties at room temperature after the above exposure conditions were determined to provide a basis for inspection of aircraft after service exposure to aerodynamic or engine heating.

Five tensile properties were determined for each exposure and test condition. Three of these, the proportional limit, modulus of elasticity, and percent elongation were tabulated and graphed in a non-dimensional form to generalize the data with respect to test material variability. Since the yield and ultimate strengths determine the load carrying ability, these tensile properties were analyzed carefully and generalizations with respect to exposure temperature and time and testing temperature were accomplished. Statistical calculations were made to determine the accuracy of the various analyses. The conclusion was reached that the yield and ultimate strength analysis is adequate for establishing design criteria in the range room temperature through 400°F, after complex exposures to times from 1.0 to 1000 hours at temperatures from 250 to 600°F.

Material, equipment, specimens and procedures are described in detail. Test results are presented in the form of tables and curves to illustrate the effect of the exposure and test conditions on the materials under investigation and the effect of normalization analyses on the generalization of the data.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Richard R Kennedy

RICHARD R. KENNEDY
Chief, Metals Branch
Materials Laboratory

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HIGH EXPLOSIVE (H.E.)

A material which normally detonates when subjected to heat or shock; it will not burn except under special conditions. High explosives are characterized by the extreme rapidity with which decomposition and blast occur. They decompose almost instantaneously either by extremely rapid combustion, or by rupture and rearrangement of the molecules themselves. In either case, gaseous and/or solid products of reaction are produced. The disruptive effect of the reaction makes a high explosive valuable as a bursting charge, but precludes its use as a propellant because the gases are formed so quickly that excessive pressures are developed which would likely burst the barrel of the weapon.

IGNITION TEMPERATURE

The minimum temperature of an explosive at which deflagration will begin within a specified time period, usually of five seconds. In the case of high explosives deflagration takes place so quickly as to produce a detonation.

INHIBITOR

A substance which is introduced into an explosive compound to stop or depress undesirable chemical reactions during storage, or to reduce the rate of chemical reaction upon explosion.

LOW EXPLOSIVE (L.E.)

See PROPELLANT

LOW-ORDER DETONATION

See DETONATION

MOHAUPT EFFECT

See SHAPED CHARGE

MUNROE EFFECT

See SHAPED CHARGE

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EFFECTS OF TEMPERATURE-TIME-STRESS HISTORIES ON THE MECHANICAL PROPERTIES OF AIRCRAFT STRUCTURAL METALLIC MATERIALS

PART I. TEMPERATURE-TIME STUDIES FOR 2024-T3 AND 7075-T6 ALCLAD SHEET

INTRODUCTION

The extension of aircraft operating speeds into the aerodynamic heating region presents an extensive and important need for information relating the effects of service temperature-time-stress histories to the mechanical properties of metallic materials. Therefore, this investigation was established through WADC by Contract AF33(616)-3024 in May 1955 to obtain such information for aircraft design and inspection purposes.

To test aircraft metallic materials under all of the complex and changing combinations of temperature, time and stress to which aerodynamically heated parts are subjected would be time consuming and economically unfeasible. However, it is feasible to sample through the range of temperature, time and stress expected during supersonic flights and from the tests performed deduce generalizations applicable to all combinations of the above variables.

The investigation consequently was limited to simple multiple temperature-time exposure sequences followed by tensile testing at room and elevated temperatures. Tests to include the variable of stress were not included in this program but are contemplated as an extension of the program.

The objectives of this investigation were specifically to (1) determine the tensile properties between room temperature and 400°F and the room temperature hardness of two aluminum alloys after single and multiple exposures in the range, room temperature through 600°F and zero through 1000 hours, (2) tabulate the data and plot the properties versus exposure time for various exposure and testing temperatures and exposure temperature for various exposure times and testing temperatures and (3) draw conclusions regarding limits for prediction of mechanical properties under complex temperature-time conditions from the relationships obtained under the simpler test conditions.

MATERIAL

Two .064" gauge, 48" x 144" sheets each of the metallic materials, 2024-T3 alclad aluminum alloy, specification QQ-A-362a, and 7075-T6 alclad aluminum alloy, specification QQ-A-287 were used for all tests of this program. For each alloy the sheets were selected from a single lot of material taken at random from stock in the production warehouse of Northrop Aircraft, Inc. From one sheet of each alloy verification tests of the room temperature tensile properties and chemical composition were determined. The properties were found to be within the limits of the applicable specifications as shown below.

Manuscript released by authors 20 December 1956 for publication as a WADC Technical Report.

ALLOYING ELEMENTS - PERCENT

	Cu	Mg	Zn	Mn	Cr	Fe	Si	Ti
			2024 (Core Material)					
Verification Test	4.12	1.64	.10	.67	.01	.23	.13	-
QQ-A-362a Limits	3.8 to 4.9	1.2 to 1.8	0.10 Max.	0.3 to 0.9	0.25 Max.	0.5 Max.	0.5 Max.	
			7075-T6 (Core Material)					
Verification Test	1.56	2.72	5.47	.026	.25	.39	.16	.074
QQ-A-287 Limits	1.2 to 2.0	2.1 to 2.9	5.1 to 6.1	0.03 Max.	0.18 to 0.40	0.7 Max.	0.5 Max.	0.20 Max.

TENSILE PROPERTIES

	Yield Strength psi	Ultimate Strength psi	Elongation % in 2" g.l.
	2024-T3 Alclad, .064 gauge		
Verification Test	43,700	67,500	20.0
QQ-A-362 Limits	40,000 min.	62,000 min.	15 min.
	7075-T6 Alclad, .063 gauge		
Verification Test	66,800	77,000	11.5
QQ-A-287 Limits	62,000 min.	72,000 min.	3 min.

TEST EQUIPMENT

The apparatus used to perform the experimental portion of this investigation consisted of:

(1) Two furnaces, one oven and one aging block for unstressed exposure of tensile specimens to elevated temperatures prior to tensile testing.

(2) A furnace for exposure of tensile specimens to elevated temperatures while tensile testing.

(3) Two universal testing machines and associated equipment for tensile testing of specimens.

(4) Three potentiometer type multi-channel temperature recorders, for multiple, continuous exposure and testing temperature records.

(5) A Rockwell hardness tester.

The exposure and testing equipment utilized in this investigation are shown in Figures 1 through 10.

Circulating Air Exposure Furnaces and Related Equipment

For unstressed exposure of tensile specimens, two Pacific Scientific Co., Du-Al 1350 furnaces shown in Figure 1 were utilized for all exposure times. These furnaces are of the circulating air type with fan located in vertical rear wall of working chamber and heating elements in vertical side walls, shielded from working chamber by double sheet metal baffles. The fan blows air to front of working chamber and then between baffles and heating elements back to fan where it is mixed and recirculated. Insulation is provided by lightweight, high temperature, insulating brick. Working chamber is 15.5 x 11 x 14 inches in height, width, and depth respectively. Rated electric power input is 5 kw maximum, rated temperature range is 200°F to 1350°F. Temperature control is by a calibrated C-A 20 guage solid wire thermocouple located in air at center of working chamber and two and one-half inches below top furnace wall.

The control system includes a Wheelco 407 Capacitrol stepless proportioning indicating controller with a zero to 1600°F range, a Wheelco 610 magnetic amplifier and a Burton 5 Kva saturable reactor. The control thermocouple voltage is fed into a galvanometer, the pointer of which indicates temperature. A vane carried by the temperature pointer acts as a valve for the heating control system. As this vane approaches the set control point, it starts to pass between the pickup coils of a single tuned grid, tuned cathode oscillator. The oscillator is designed to give maximum oscillation when the vane is at or above the set temperature control position.

Proportionally less and less oscillation occurs over a band of temperatures below the set control position as the temperature difference between the vane and set control position increases. The action of the oscillator controls the output signal voltage of the 407 controller. Maximum oscillation gives minimum signal voltage and vice-versa. The signal voltage is fed to the 610 magnetic amplifier (pilot reactor) where the signal power is boosted sufficiently to provide the strong magnetic field necessary to saturate the Burton load reactor. When fully saturated due to maximum control signal power the load reactor delivers maximum power to the heating elements. Conversely, minimum power is delivered to the heating elements when the load reactor has minimum saturation, i.e., when minimum control signal power is received. Rated accuracy of the 407 controller is 0.25% of full scale temperature range. The input voltage to the control system is stabilized by a voltage regulator to prevent drift in the temperature control point.

To provide a more constant exposure temperature and a greater rate of approaching exposure temperature for the tensile specimens than are possible with air contact, specimens were placed on metallic plates within the above furnaces. For 0.1 and 1.0 hour exposures the double platen heater shown in Figure 2 was used. These platens were designed to provide a constant temperature heat sink during the insertion and removal of specimens from the exposure furnace. In addition, as the result of being sandwiched between the platens the specimens approached and reached the exposure temperature in less than 30 seconds permitting close control of exposure time. Essentially, the platens are two large masses of aluminum and steel which are heated by the furnace to the correct exposure temperature. Each platen is solid aluminum block, 2.75 x 9 x 13 inches, surrounded on five sides by .375 inch steel plate. Due to its lower heat conductivity as compared to aluminum, the steel plate is used to reduce heat losses in the platens during periods of loading and unloading. specimens. The mating surfaces of the platen are aluminum for good heat conduction during exposure of specimens. The upper platen is lifted as needed by a detechable lever arm.

For the 10, 100, and 1000 hour exposures in the above furnaces the temperature stabilizing plates shown in Figure 3 were used. These plates also provided a constant temperature heat sink for the specimens, and the somewhat longer time to reach exposure temperature is negligible in relation to the exposure times.

Circulating Air Oven and Related Equipment

This oven, shown in Figures 1 and 4, was constructed some years ago by Northrop for elevated temperature use up to 500°F. It is of the circulating air type with external fan which blows air through a duct into the bottom of the work chamber through the rear vertical wall and exhausts the air at rear of top wall into the return duct. There are two separately controlled electric heating units: a 2.1 Kw finned unit located in the inlet air duct; and a 1.25 Kw unit on a vertical baffle near the rear wall of the working chamber. Insulation is provided by transite sheet and glass wool batting. Working area is 20 x 11 x 15 inches in height, width, and depth respectively.

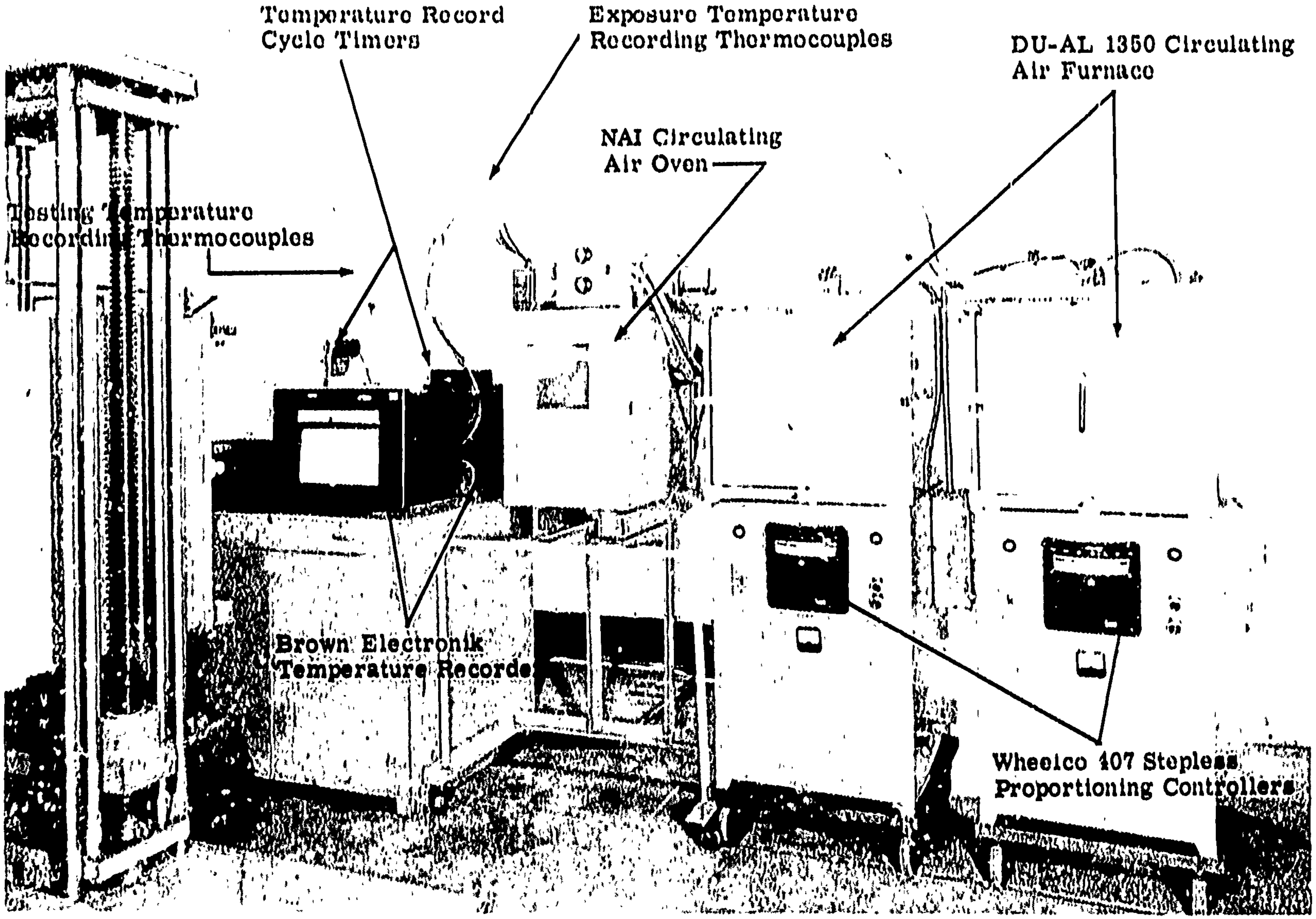


Figure I. Elevated Temperature Exposure Apparatus Showing Circulating Air Furnaces, Circulating Air Oven, and Temperature Recorders

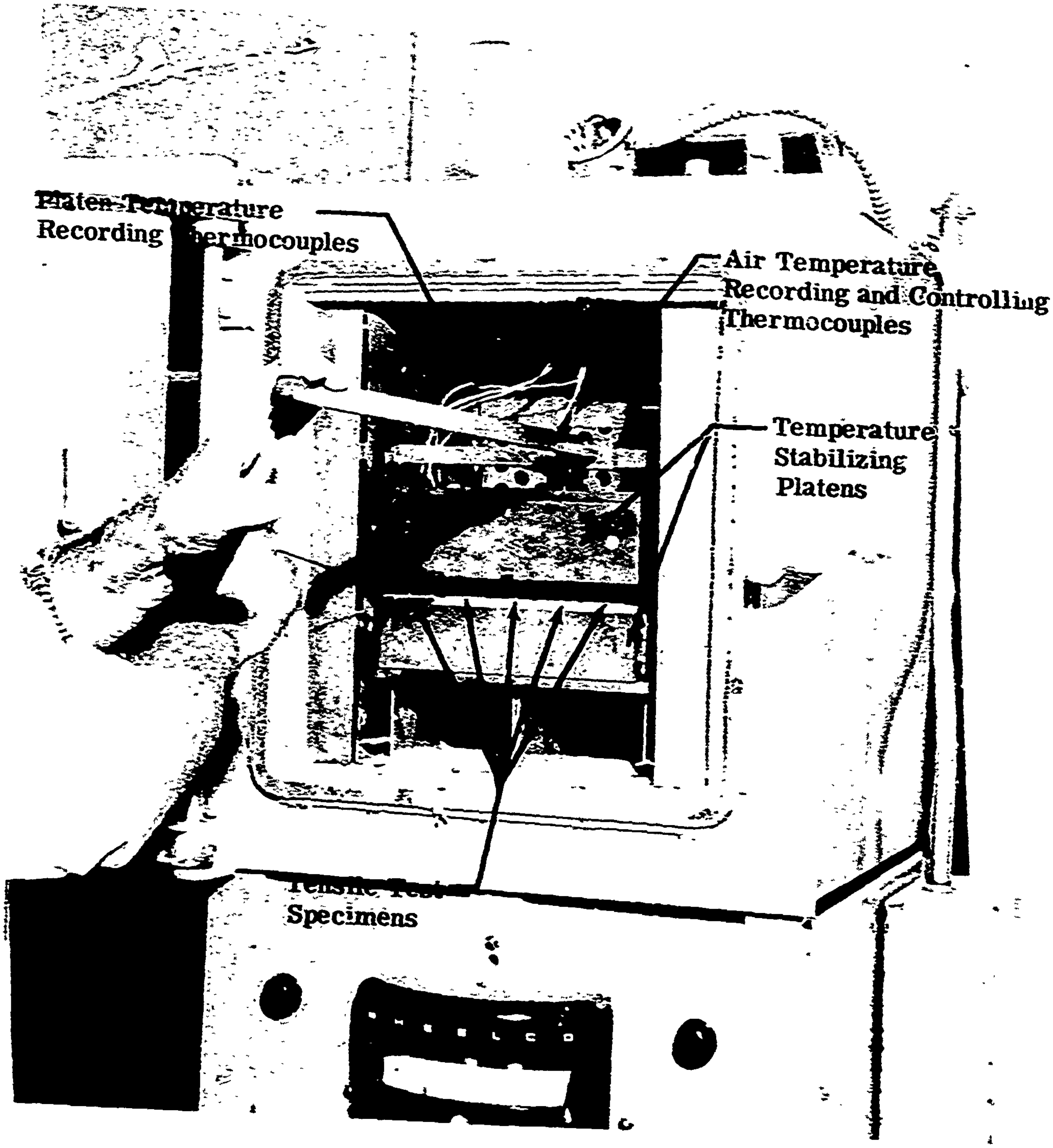


Figure 2. DU-AL 1350 Circulating Air Furnace Interior Showing the Stabilizing Platens Used for the 0.1- and 1.0-Hour Exposures, Tensile Test Specimens, and Controlling and Recording Thermocouples

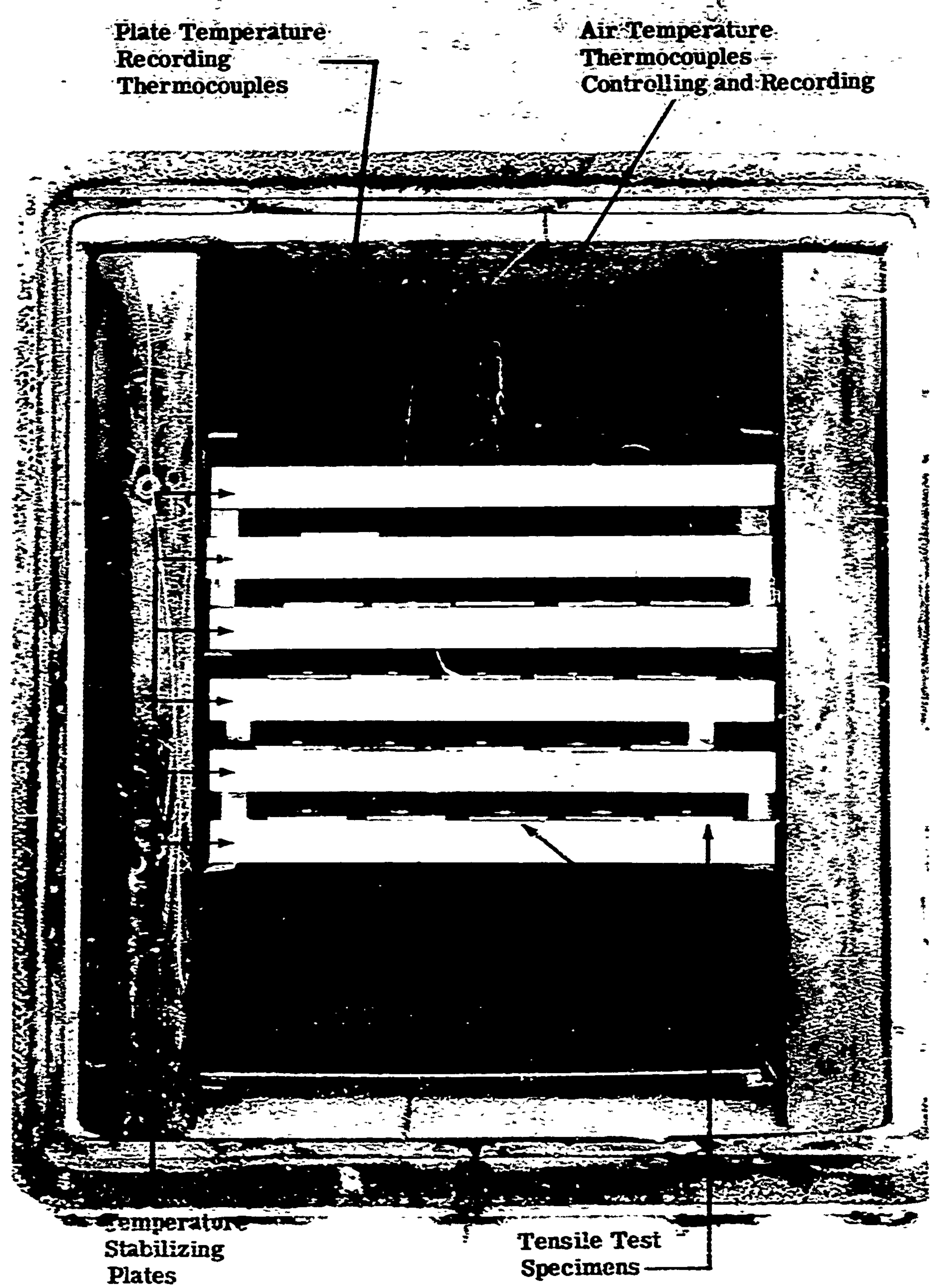


Figure 3. DU-AL 1350 Circulating Air Furnace Interior Showing Temperature Stabilizing Plates, Tensile Test Specimens, and Controlling and Recording Thermocouples

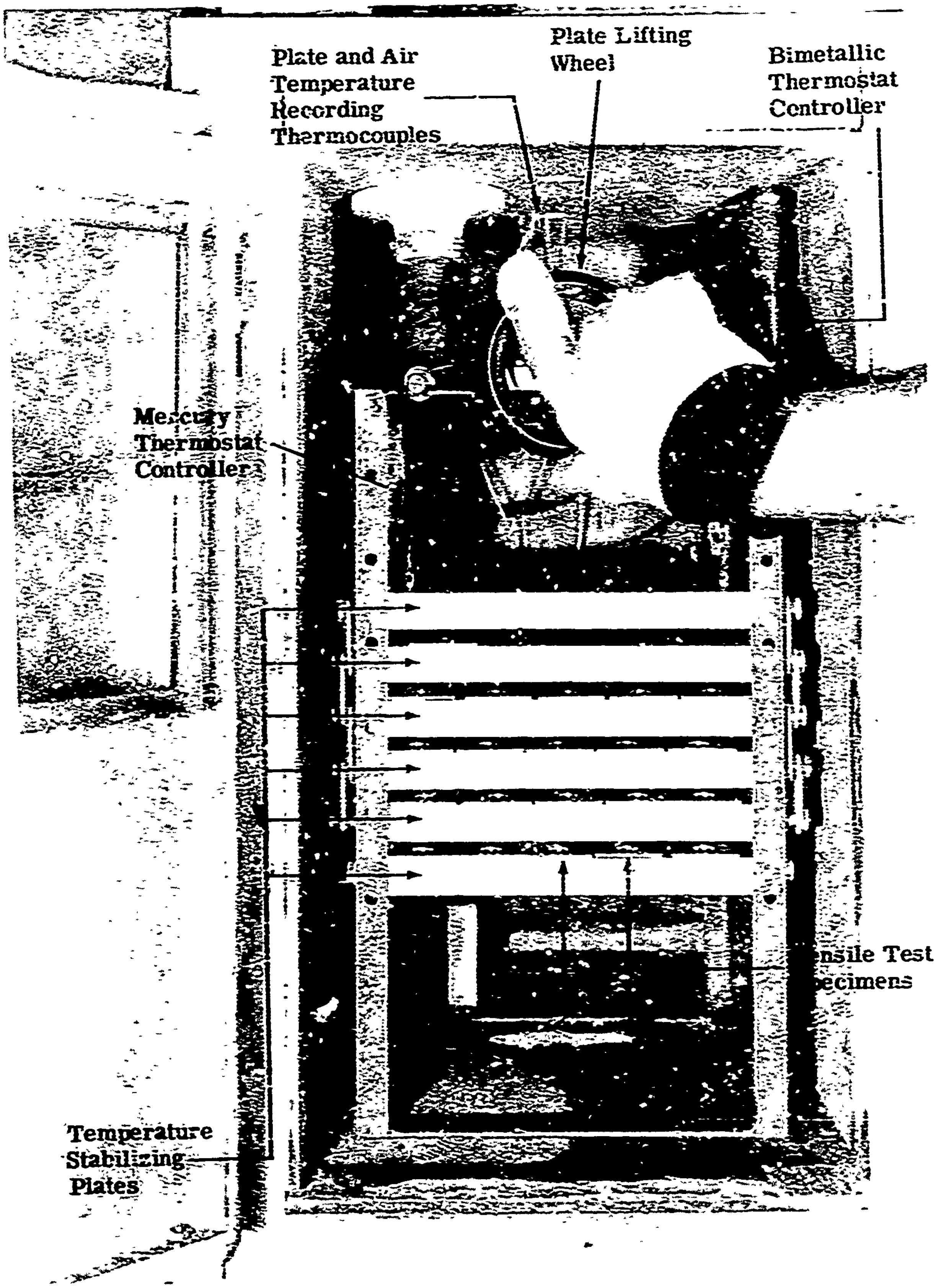


Figure 4. [illegible] Circulating Air Oven Interior Showing Temperature Stabilizing Plates, Tensile Test Specimens, Recording Thermocouples, and Controlling Thermostats

A Fenwal thermostat, located at upper left corner of working chamber, controls the 2.1 Kw heater. A Chromalox #AR-5524 sealed mercury type thermostat controls the 1.25 Kw heating unit, and the sensing element of this thermostat is centered in front of the vertical baffle at the rear wall of working chamber.

Temperature control of the air in this furnace is rather poor with about ± 20°F variation about control point after stabilization. However, metal to metal contact of specimens between the aluminum plates of the fixture shown in Figure 5 reduced exposure temperature variation of the specimens to acceptable limits. This fixture has provision for raising and separating the individual plates to permit insertion of specimens between the plates.

This furnace was pressed into service for 10 and 100 hour exposures during the sequential exposure tests when it was found that at least three furnaces were required to permit time for temperature stabilization of furnaces.

Aging Block

As an alternate third specimen exposure furnace during occasional breakdown and repair of some of the above furnaces, the Comet Model 600 laboratory aging block shown in Figure 5 was used for some 100 hour specimen exposures. This block consists of a solid precision machined block of aluminum about 18 inches in diameter and 15 inches high with 13 wells, each open at the top. The wells are 1.75 inches in diameter and 11 inches deep. An aluminum plate completely covers the bottom of the block and is removable for ease of maintenance. The wells are symmetrically arranged in the block on a 10.5 inch centerline diameter. Five 500 watt, 220 volt, 60 cycle heater cartridges are arranged symmetrically in holes in the block on a five inch centerline diameter. Unit is designed for close temperature control from 100°F to 600°F. Manufacturer is Product Packaging Engineering , Culver City, California.

Two temperature controllers in series with each other and with the heating cartridges are used for control. A Fenwal Thermostat, Model 17352, located in a hole in the center of the aging block, is set slightly higher than the operating temperature of the Partlow instrument and acts as a safety instrument to prevent temperature override in case of malfunction of the Partlow instrument. The Partlow Indicating Temperature Control, Model E18R 6X1P110, controls the temperature of the unit. It is a mercury bulb, impulse type, proportioning thermostatic control incorporating a stiff-leaf spring attached to a switch as the proportioning device. The spring-switch is attached to and follows the movement of the block temperature indicating pointer arm. This pointer arm is moved up or down the temperature scale in response to the expansion or contraction of the mercury bulb sensing element. As the pointer approaches the control proportioning band, the switch approaches, as constantly turning cam. At the lower edge of the proportioning control band, the switch contacts the high point of the cam and opens for a very short time each cycle. At upper edge of the proportioning band the switch is opened for all of the cycle and power is furnished continually. The control point will be at some temperature within the proportioning band depending on the power required to just maintain a constant temperature. For this instrument, width of proportioning band is

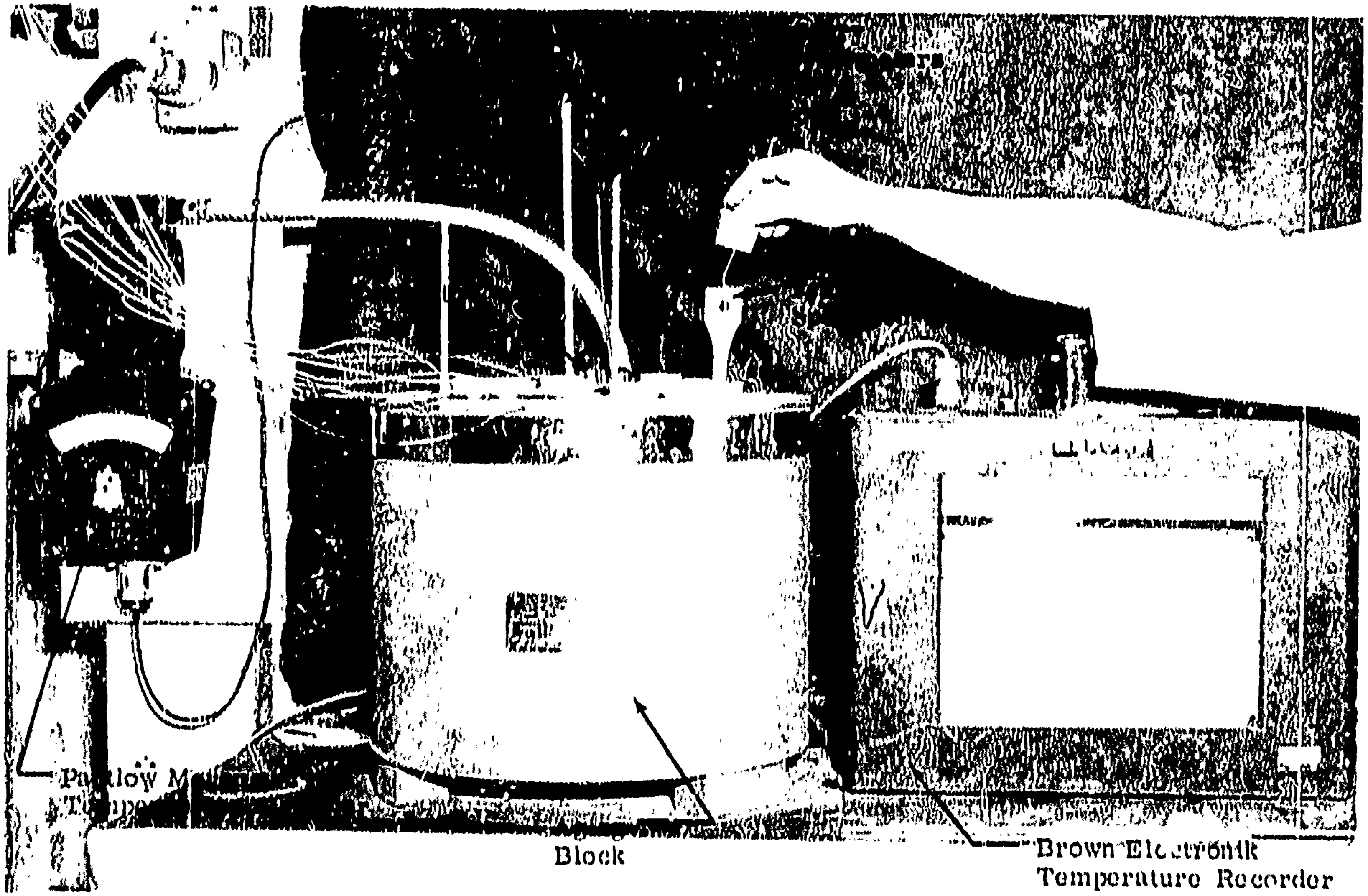


Figure 5. Aging Block Used for 100-Hour Elevated Temperature Exposures with Temperature Controlling and Recording Instruments

50°F: Scale range is 100-650°F; line voltage is 220V, 60 cycle. The Partlow instrument mercury bulb is located in a hole in the aging block between two of the wells.

Circulating Air Testing Furnace & Related Equipment

The Pacific Scientific TM82020AS Testing furnace was used for all exposures of tensile specimens during tensile testing. This furnace, shown in Figure 6, is of the circulating air type with fan located in vertical rear wall of working chamber and heating elements in vertical side walls, shielded from working chamber by double sheet metal baffles. The fan blows air to front of working chamber and then between baffles and heating elements back to fan where it is mixed and recirculated.

Insulation is provided by lightweight, high temperature, insulating brick. Working chamber is 20 x 7.5 x 20 inches in height, width, and depth respectively. Rated electric power input is 7 kw maximum. Rated temperature range is 200°F to 1000°F.

Temperature control is by a calibrated C-A 20 gauge solid wire thermocouple located near test specimen in working chamber. The temperature control instrument is a Minneapolis-Honeywell Brown Electronik recorder, 0-1200°F range, with an Electropulse time proportioning relay. By proper adjustment, this control turns the heater power on and off in a series of pulses, varied so that the temperature control position is approached at the optimum rate and reached without overshooting. Overall calibrated accuracy of the recorder is 0.25% of full scale temperature range.

Temperature Recorders

Three Brown Electronik potentiometer type strip chart temperature recorders were utilized to record temperatures during specimen exposure and testing. These instruments are equipped with one second, 12-point printing wheels and an additional timer to permit recording for 30 seconds every 30 minutes during 10, 100 and 1000 hour exposure periods. Continuous 12 point cycle recording was used during the 0.1 and 1.0 hour exposure tests. Each recorder has a rated accuracy of 0.25% of full scale temperature range. Two of the recorders have a full scale of 0. to 600°F and the other -75 to 575°F. Thermocouples used with the recorders are 20 gage solid I-C (B-S) wire, calibrated at Northrop by comparison with secondary standard thermocouples.

5000 lb. Capacity Universal Testing Machine

The Baldwin-Tate-Emery, Model PTE, universal testing machine of 5000 lb. maximum capacity shown in Figure 7 was used for tensile testing in all but the last series of sequential exposure tests (Tables XXVII & XXXII). This machine incorporates an Emery hydraulic load measuring cell and a Tate-Emery hydraulic-pneumatic load indicator. The load indicator has four ranges 5000 lb., 1000 lb., 200 lb., and 50 lb. However, only the first two ranges were used. These ranges are rated to have an error less than 0.5% of load reading or one

division, whichever is greater. The least scale divisions are 5 lb. for the 5000 lb. load indicator range and 1 lb. for the 1000 lb. range. The machine is capable of loading in either tension or compression.

Loading and straining occurs when the crossheads are separated by the mechanical power system. Straining crosshead is driven by two screws which are rotated by a gear drive. The gear drive is powered by a DC motor (one HP) through a two-speed chain drive transmission. Variable crosshead separation is provided through electronic control of the power input to the DC motor. Any setting of the speed control rheostat provides a constant rate of crosshead separation at that setting. Crosshead separation rates are steplessly variable in two ranges, 0.0025 to 10 inches per minute or 0.005 to 20 inches per minute.

For tensile testing hemispherical self-adjusting loading seats in test machine crossheads connect to high temperature extension loading rods, pin-joint specimen loading heads and tensile specimens. Figures 6, 7, 8, 9, and 10 show details of specimen loading assembly.

To graph load versus strain this machine incorporates a Baldwin MA-1, microformer type recorder as shown in Figure 6. The pen of this recorder is attached mechanically to the load indicating pointer of the machine to record load. The recorder drum with graph paper rotates in response to a strain follower extensometer signal to record the strain in a tensile specimen. Minimum load division on recorder graph is 0.01 of recorder load range. Graph record is on a drum permitting a maximum chart length of 12 inches for strain recording. Possible strain record magnifications with either the Baldwin PS-5M or PSH-8MS strain follower (extensometer) are 250:1, 500:1, and 1000:1. During this program only the 250:1 magnification with a minimum graph division of 0.0004 inch strain was utilized.

Figure 6 shows a typical test assembly in the furnace.

120,000 lb. Capacity Universal Testing Machine

A Baldwin-Tate-Emery Universal testing machine of 120,000 lb. maximum capacity was used for the last series of sequential exposure tests in this program because of repairs and alterations to the 5000 lb. capacity machine. This machine incorporates an Emery hydraulic load measuring cell and a Tate-Emery hydraulic-pneumatic load indicator. The load indicator has three ranges 120,000 lb., 24,000 lb., and 6,000 lb. Only the lowest load range was used. This range has a least division of 5 lb. and a rated maximum error of 0.5% of load or 0.10% of range, whichever is the greater. The machine is capable of loading in either tension or compression.

Loading and straining occurs when the crossheads are separated by the ram of the hydraulic power system. The rate of crosshead separation is controlled by two hydraulic valves, one for loading and one for unloading the crossheads. Crosshead separation rates are steplessly variable from zero to six inches per minute. Any setting of the loading or unloading valve provides

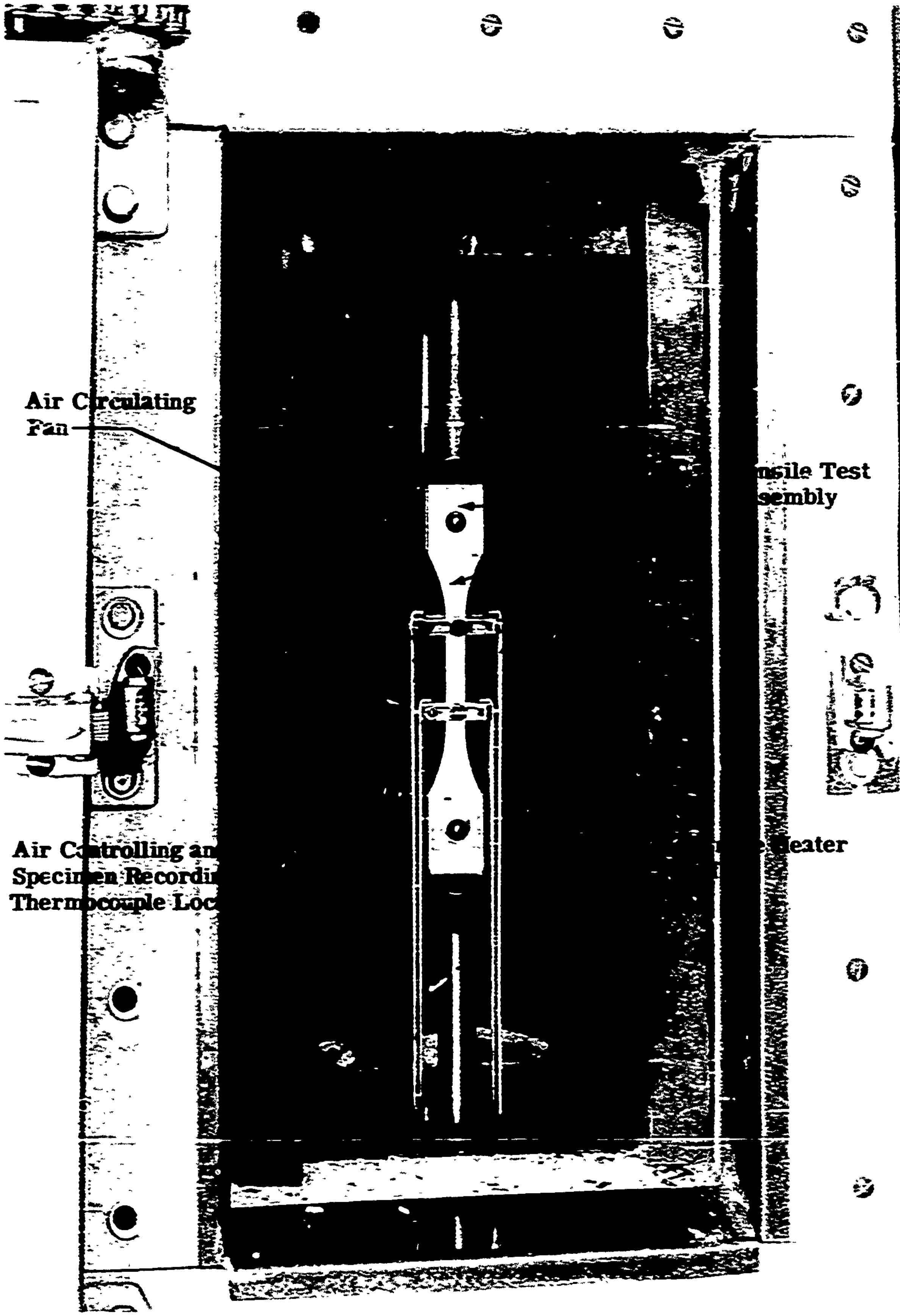


Figure 6. Elevated Temperature Tensile Testing Apparatus Showing Interior of Circulating Air Test Furnace and Tensile Testing Assembly

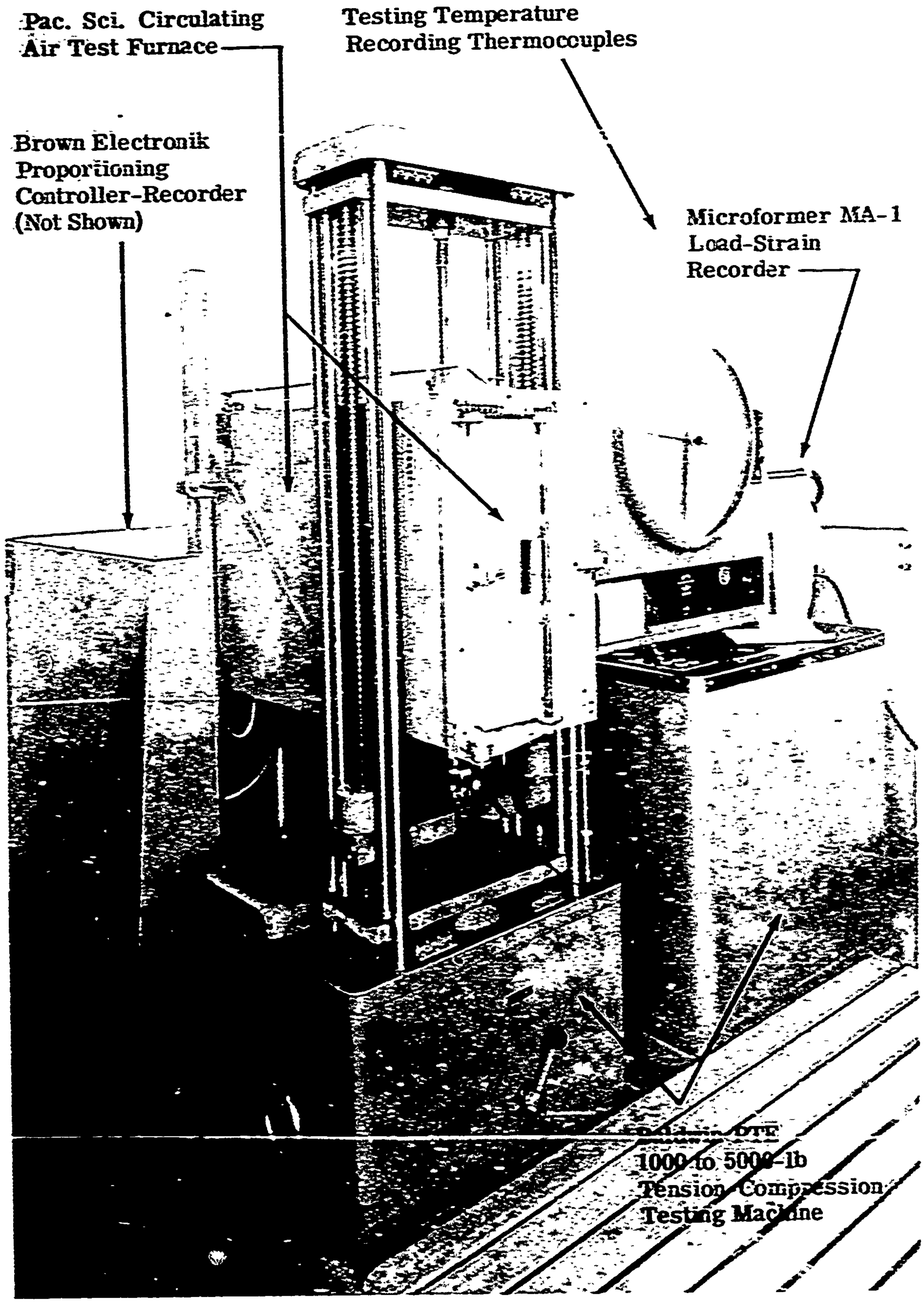


Figure 7. Elevated Temperature Testing Apparatus Showing Circulating Air Test Furnace, Tension Testing Machine, and Microformer Recorder

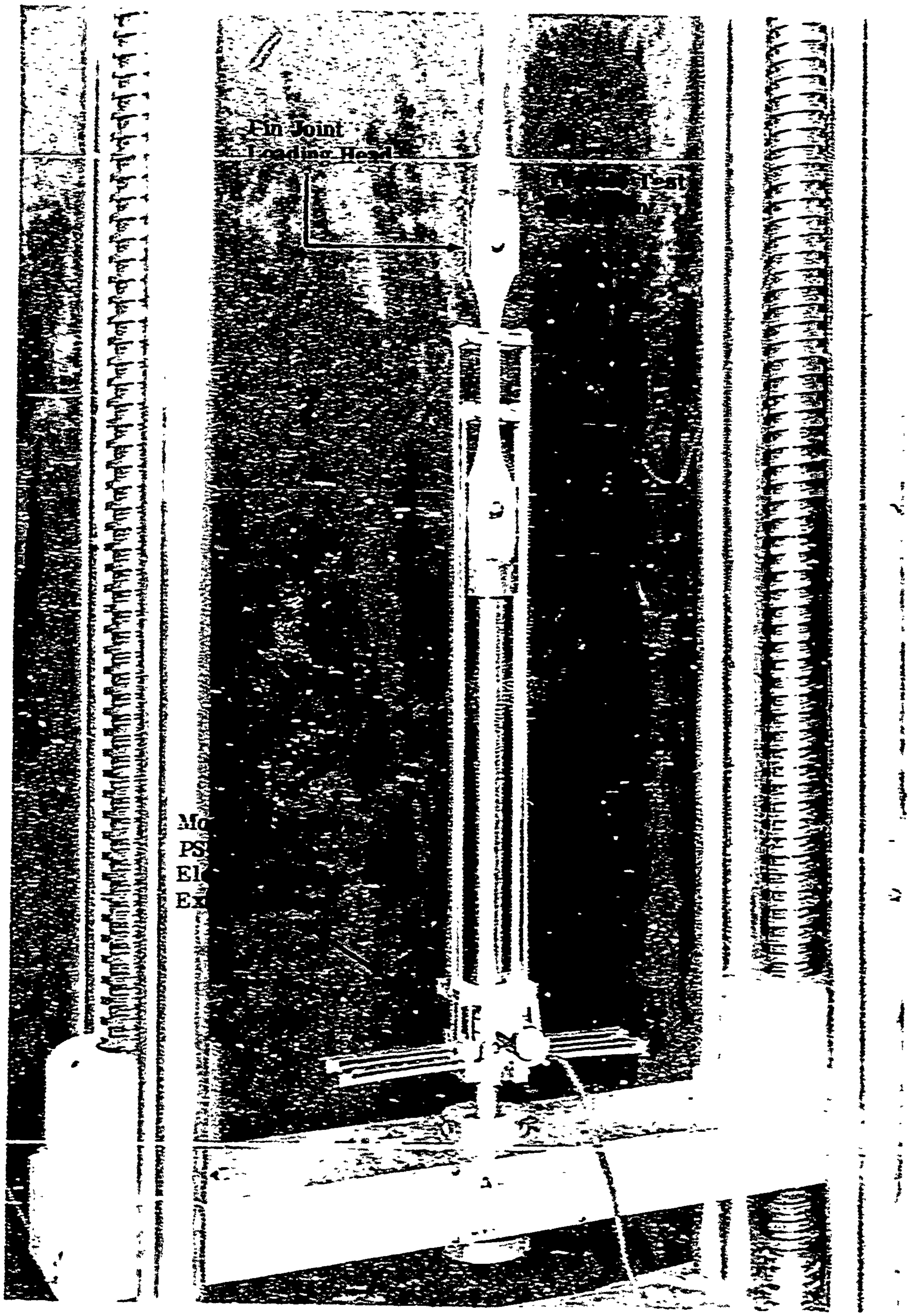


Figure 8. Elevated Temperature Tensile Testing Assembly Showing Extensometer, Tensile Test Specimen, and Pin Joint Loading Heads

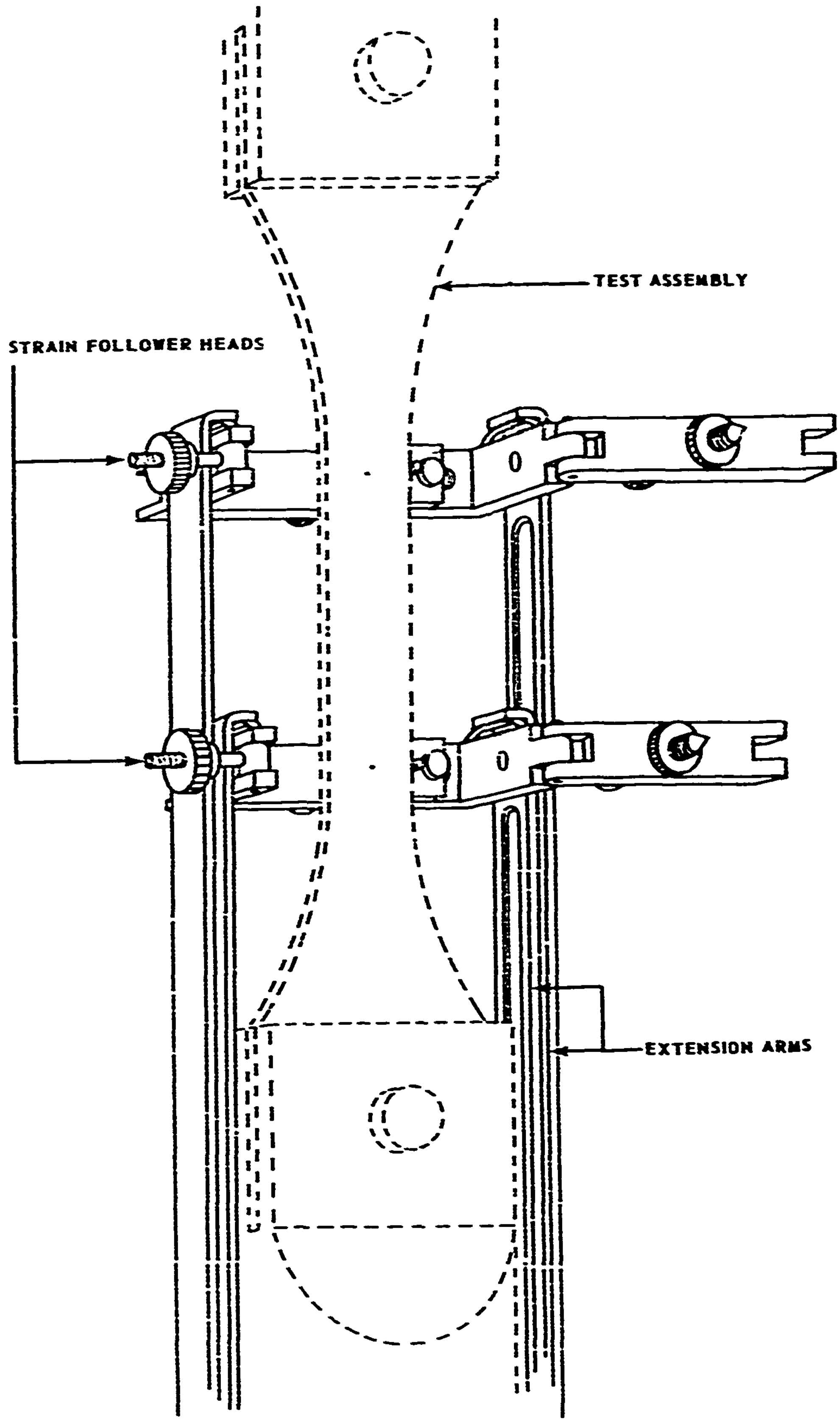


Figure 9. Modified Strain Follower Head and Extension Arms for Baldwin PSH-8MS Extensometer

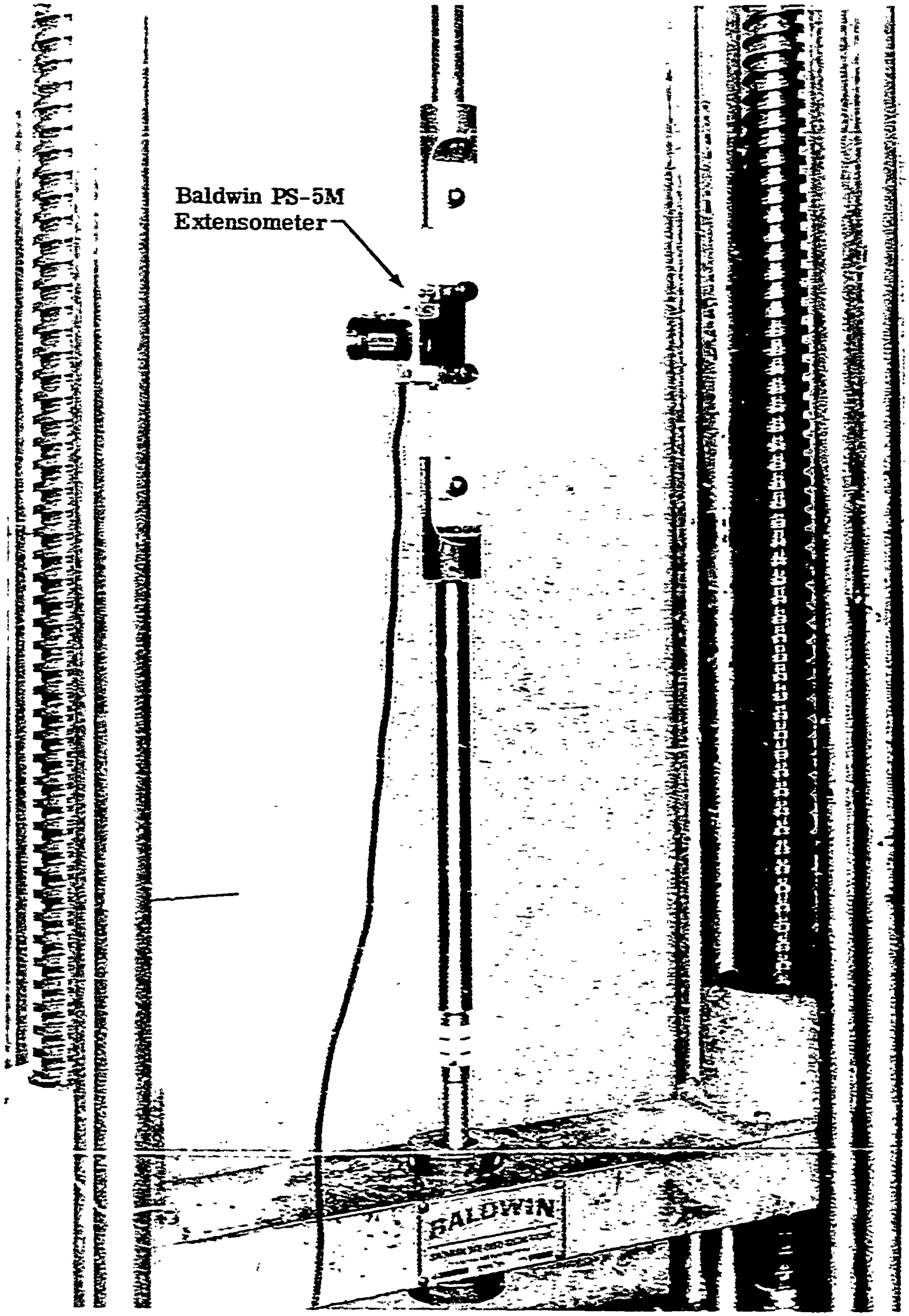


Figure 10. Room Temperature Tensile Testing Assembly

a constant speed of the hydraulic ram.

For tensile testing the same specimen loading assembly is used with this machine as with the 5000 lb. machine.

To graph load versus strain the same type of recorder is incorporated with this machine as with the 5000 lb. machine.

Room Temperature Extensometer

A Baldwin PS-5M strain follower extensometer was used for strain measurements during all room temperature tensile tests. This extensometer is of the averaging, separable type incorporating conical points for contacting opposite sides of the test specimen, a two inch gage length and .04 inch maximum extension. It can be used in testing flat and round specimens with maximum dimensions of .505 inches square or .505 inches diameter. A typical room temperature testing assembly is shown in Figure 10.

Elevated Temperature Extensometer

A Baldwin PSH-8MS strain follower extensometer was used for strain measurements during all elevated temperature tensile tests. This extensometer is of the averaging, separable type incorporating conical points for contacting opposite sides of the test specimen, a two inch gage length and .04 inch maximum extension during testing. It is designed for use at temperatures up to 1600°F on sheet, plate, and round specimens with maximum dimensions of .505 inches square or .505 inches diameter. This extensometer has been modified using longer extension arms and a specimen strain follower head of Northrop design. The strain measuring lever and microformer coil system is unchanged. Figure 9 shows details of the strain follower heads and extension arms in relation to a tensile test specimen while Figure 8 shows details of a typical extensometer, tensile specimen assembly.

Hardness Tester

Two Rockwell standard hardness testers, one model 3R and one model 4JR-P1, manufactured by the Wilson Mechanical Instrument Division of American Chain and Cable Co. were used to determine the hardness of tensile test specimens. Instrument accuracy was determined periodically by comparing instrument readings with known hardness of a calibrated test block.

EXPERIMENTAL PROCEDURES

The experimental portion of this investigation consisted of:

(1) Preparation of tensile specimens.

(2) Unstressed exposure of tensile specimens to selected temperature - time conditions.

(3) Tensile tests at selected temperatures with and without prior unstressed exposure.

(4) Room temperature tensile tests of specimens from each material panel for comparison with above tensile tests.

(5) Determination of inherent errors in measuring temperature, time, load and strain.

(6) Measurement of room temperature hardness on all specimens tested at room temperature.

Specimen Preparation

Each sheet used for testing was cut into panels large enough for 14 specimens placed side by side and the axis of each specimen transverse to the rolling direction of the sheet. Each panel was designated with a letter, starting with A and going to Z, then to AA, BB, etc. The panels were used in this sequence. The twelve outer specimens in each panel were numbered consecutively from one to twelve and used for elevated temperature exposure and testing. The middle two specimens were numbered C1 and C2 and used for room temperature control tests with which to compare the elevated temperature tests of the same panel. The complete designation for each specimen was typically

2A1, 7Z12, 2MC1

where the first digit designates the alloy, 2 for 2024 and 7 for 7075, the first letter designates the panel, the second letter, C, designates room temperature control specimen, only, and the second number or pair of numbers designates the specimen.

This panel system of specimens was adopted primarily to minimize the material variability factor in data analysis.

Each specimen was machined to the configuration of Figure 11. This pin joint configuration was chosen since it was believed that improved alignment and more uniform stressing could be obtained than with the standard QQ-M-151 specimen clamped in jaws. In addition, for elevated temperature testing the pin joint type specimen was assembled more easily and rapidly than the standard type, thus causing less temperature drop of the testing furnace during assembly of specimen and less recovery time to the testing temperature.

To prepare the specimens, panels were cut into individual specimen blanks with their axis in the direction transverse to the original sheet rolling direction. Then, eight blanks at a time were milled in a fixture to the required length, width, and reduced test section. Next each specimen was fastened securely in a simple drill fixture which assured correct alignment of the holes with respect to the test section and each pin joint hole drilled. Finally, the milled edges and surfaces of the reduced test section of each

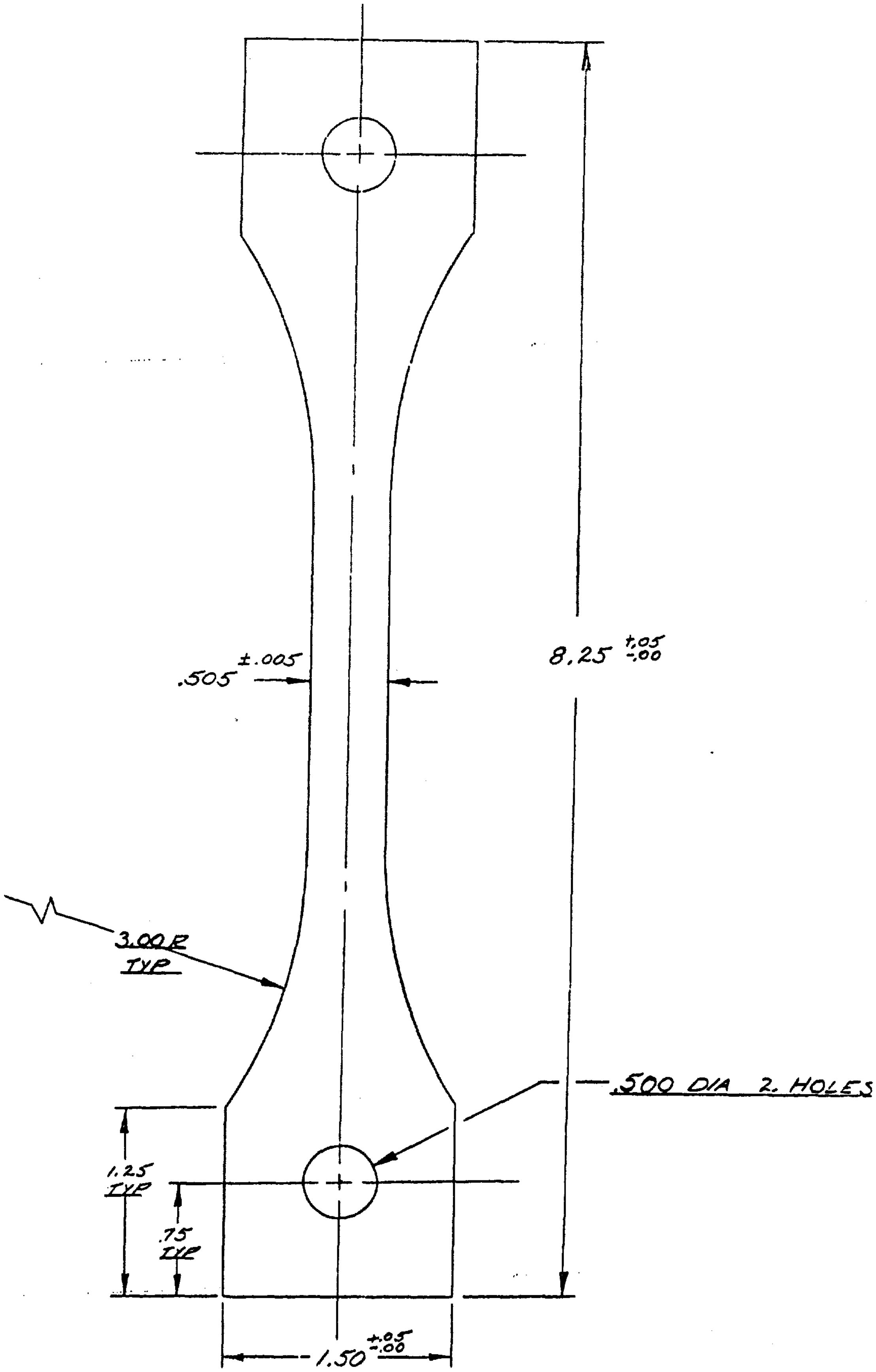


FIG. 11 TENSILE TEST SPECIMEN (PIN JOINT TYPE)

specimen were smoothed of all milling marks and surface scratches with 400 grit paper, the resultant finishing marks being in the axial direction only.

Unstressed Exposures

Specimen exposure conditions were confined to sampling the temperature-time span in which aluminum alloys would be structurally useful when subjected to aerodynamic heating. Single exposures as well as sequences of exposures were investigated. To each single or sequential multiple temperature-time condition a different group of twelve specimens were exposed. During exposure none of the specimens were subjected to externally applied stresses.

First, a series of single exposures were performed as follows to serve as a basis for comparison with the more complex exposure conditions.

Single Exposure Conditions

2024-T3		7075-T6	
Temp., °F	Time, Hours	Temp., °F	Time, Hours
300	0.1, 1.0, 10, 100, 1000	250	100, 1000
400	0.1, 1.0, 10, 100, 1000	300	0.1, 1.0, 10, 100, 1000
500	0.1, 1.0, 10, 100, 1000	400	0.1, 1.0, 10, 100, 1000
600	0.1, 1.0, 10	500	0.1, 1.0, 10, 100, 1000

Then a series of simple, sequential exposures were performed as follows to approximate complex exposure conditions. These exposure sequences were arranged before testing to attempt to adequately sample the useful temperature-time span for the subject alloys.

Sequential Exposure Conditions

Sequence Number	1st Exposure 1.0 Hour	2nd Exposure 10 Hours	3rd Exposure 100 Hours	4th Exposure 1000 Hours
	2024-T3 Alloy			
1	500°F	400°F	-------	-------
2	500°F	400°F	300°F	-------
3	600°F	500°F	-------	-------
4	600°F	500°F	400°F	-------
5	600°F	500°F	400°F	300°F
	7075-T6 Alloy			
6	400°F	300°F	-------	-------
7	400°F	300°F	250°F	-------
8	500°F	400°F	-------	-------
9	500°F	400°F	300°F	-------
10	500°F	400°F	300°F	250°F

Finally, an additional series of simple sequential exposures were performed as follows to fall entirely on the critical inclined portion of modified Larsen-Miller curves as determined from analysis of data from the first and second series of exposure tests.

Additional Sequential Exposure Conditions

Sequence	1st Exposure		2nd Exposure		3rd Exposure		4th Exposure	
	Temp. °F	Time, Hrs.	Temp. °F	Time, Hrs.	Temp. °F	Time, Hrs.	Temp. °F	Time, Hrs
				2024-T3 Alloy				
11	600	1.0	555	5.1	510	18.7	465	99.6
12	555	1.0	510	4.3	465	21.5	420	126.1
13	510	1.0	465	4.6	420	25.2	375	165.0
14	465	1.0	420	5.0	375	30.0	330	219.0
				7075-T6 Alloy				
15	500	1.0	460	3.9	420	17.6	380	90.5
16	460	1.0	420	4.2	380	20.2	320	113.4
17	420	1.0	380	4.5	340	23.4	300	145.1
18	380	1.0	340	4.8	300	27.7	260	191.7

The method of exposure included rapidly heating test specimens to the required temperature, soaking for the required combination(s) of temperature and time in circulating air furnaces, ovens and aging block, and transferring as rapidly as possible between furnaces or to the tensile testing equipment. The method was designed especially for the shorter (0.1, 1.0 and 10 hour) exposure periods, i.e., tensile specimens were inserted in the furnace so as to minimize the time to reach the exposure temperatures with the minimum possible deviation and transferred to the next exposure furnace or tensile testing machine in the minimum possible time.

During the 0.1 and 1.0 hour exposures specimens were inserted between the platen heaters shown in Figure 2. With these platens the time to reach exposure temperature and the temperature deviation during exposure were the least of any of the exposure methods utilized. Further, the furnace doors could be opened without changing the temperature of . heated platens or specimens already on the platens, thus permitting sequen.. insertion of the specimens. Measurement of exposure time started at the moment a specimen was inserted between the platens and ended the moment the furnace door was opened to remove the specimen. The time for specimens to reach within 5°F of the maximum soaking temperature, 600°F, was 15-25 seconds. The time from opening the furnace door to removing a specimen was 5-10 seconds.

During the 10 hour and longer exposures specimens were sandwiched between or laid upon 0.75" thick aluminum plates in the circulating air furnaces shown in Figures 3 and 4 or suspended by wires from corks and suspended in air in plugged individual wells of the aging block shown in Figure 5. Time to reach the exposure temperature for these longer exposures was negligible (0.1% or less

of exposure time) in comparison to the exposure times. The temperature of specimens already on the aluminum plates or in an aging block well were not changed by opening a furnace door or removing the cork from adjacent aging block wells, thus permitting sequence insertion of specimens. Exposure time measurement started the moment a specimen was laid on an aluminum plate or inserted in an aging block well and ended the moment the furnace door was opened or cork removed from aging block well

Temperature measurement during exposure was by 20 gauge solid wire iron-constantan thermocouples. These thermocouples were calibrated prior to use by comparison with a platinum - 10% rhodium, platinum thermocouple which had been standardized within the previous six months at the National Bureau of Standards. Temperature recording thermocouples were imbedded in the platens and plates .05 inch below surfaces contacting specimens or inserted in aging block wells adjacent to specimens. Three or more couples were utilized to record temperatures at the minimum, mean and maximum temperatures of each furnace or aging block. Each thermocouple temperature was recorded on one of the Brown "Electronik" potentiometer type recorders shown in Figures 1 and 5 at intervals of 30 minutes during 1.0 hour and longer exposures and at intervals of 15 seconds during 0.1 hour exposures and the start and end of all exposures.

Deviation of recorded specimen temperatures from the nominal temperatures listed above and in the data tables was $\pm 2\frac{1}{2}$°F or less for all 0.1 hour and 1.0 hour single exposure conditions and $\pm$ 5°F or less for 10 hour and longer single exposure conditions as well as all the sequential exposure conditions, with the following exceptions:

Further deviation of the actual exposure temperatures from the listed nominal temperatures is possible for the following reasons: (1) Temperature readings of the calibrated thermocouples varied from the equivalent standard thermocouple readings up to $\pm$ 1°F throughout the exposure temperature range, (2) the N.B.S. standardized thermocouples used for calibrating the recording thermocouples are certified to have no more than $\pm$ 0.9°F error or departure from the standard Iron-Constantan temperature emf relationship, (3) the maximum error in Brown strip chart temperature records was $\pm$ 1°F when determined by substituting accurate voltages to simulate thermocouple signals in the recorders. Since corrections for these errors were not made during testing, a $\pm$2.9°F additional deviation of actual temperature from the listed values in the data tables is possible.

Tensile Testing

Following unstressed exposure, each group of twelve specimens, representing one single or sequence exposure condition, was separated into subgroups of three specimens each and a different sub-group tensile tested at each of the following exposure temperatures:

Room Temperature
200°F
300°F
400°F

In addition to the above test three specimens each of each alloy were tested at 200, 300 and 400°F without prior exposure to serve as a zero exposure reference with which to compare all other exposure tests. Also, two tensile specimens from the middle of each panel (see Specimen Preparation) were tensile tested at room temperature in the "as received" condition.

During testing the sequence of events consisted of (1) taking a specimen from an exposure furnace or aging block, (2) transferring the specimen about fifteen feet to the tensile testing equipment, (3) opening the test furnace door and assembling the specimen into the loading heads, (4) closing the test furnace door and applying and maintaining a small load on the specimen, (5) opening the furnace door and attaching the extensometer to the specimen, (6) closing the furnace door and adjusting and maintaining the load at a slightly higher value, (7) heating the specimen until the required temperature is reached and (8) starting the tensile test.

Transfer time of each specimen including the time the exposure furnace door or aging block well was opened until the specimen and extensometer were completely assembled and started to heat to the testing temperature was no more than 60 seconds. The time required to heat a specimen to the testing temperature depended on the recovery rate of the testing furnace and varied from 7 minutes for the 200°F testing temperature to 12 minutes for the 400°F testing temperature. The exposure time at elevated temperature during tensile testing depended on the length of the tensile testing period and was about 0.4 minute for each percent elongation a specimen withstood. Testing time varied from about 3 minutes for specimens with 7 percent elongation to about 33 minutes for specimens with 82 percent elongation.

During each tensile test the rate of testing machine crosshead travel was held constant and was selected to give a strain rate, prior to yield, as nearly .005 in./in./min. as possible. Since some yielding in bearing at the pin joint holes occurred on some specimens because of the large range of exposure and testing conditions the rate of crosshead travel was varied somewhat so as to maintain a nominal .005 in./in./minute strain rate prior to yield. The strain rate and head travel rate of each specimen are listed in the data tables.

The load-strain measuring system composed of extensometers to follow the strain on a two inch gage length of each specimen, a mechanical linkage between the tensile machine load measuring system and an autographic recorder to follow the load, and an autographic load-strain recorder to continuously graph the load strain curve up through the yield point during testing was utilized to provide data for calculation of the modulus of elasticity, proportional limit and yield strength.

The system error in strain readings was determined for each extensometer

by several calibrations at periodic intervals throughout testing. Calibration equipment consisted of a Baldwin strain follower calibrator and a set of calibrated Hoke gage blocks. Each calibration consisted of comparing autographic recorder readings versus gage block dimensions for five to ten increments of strain through the useful range and averaging the results for three or more runs. Error in the Hoke gage blocks (.000003" in./in. maximum) was 7 to 180 times smaller than the error in the strain measuring system and was considered negligible. Error in the strain measuring system is shown in Table I and is 10% or less of any strain. The errors of Table I remain uncorrected in calculation and tabulation of the data.

The load indicator reading on the testing machine at maximum load was used to provide data for the calculation of the ultimate strength. The load indicator errors and the autographic recorder errors were determined for each testing machine with standardized dead weights and proving rings. Both the load indicator and autographic recorder errors are shown in Table II and are 1% or 6% respectively for any load. Each calibration shown is the average of three or more runs at the stated loads.

Gage marks, 2.000 inches apart on the original test specimens were used to determine the total percent elongation after fracture. Dividers were used to determine length between gage marks on mated halves of fractured specimens. Accuracy of measurement was .01 inches or 0.5% elongation.

Hardness Testing

After completion of testing, hardness determinations were made on all specimens that had been tensile tested at room temperature. Rockwell hardness indentations were made only near the unstressed four corners of the pin joint loading section of each half of each specimen. Each hardness value listed in this report on the average of three or more hardness readings. Early in the hardness tests it was discovered that two hardness scales, B scale and H scale, were necessary. The range of mechanical strength and hardness was so great that the softer specimens exhibited the anvil effect, i.e., the work hardening of the specimen extended completely through and was visible on the opposite side from the impression. The "B scale" with a 100 kilogram load and a 1/16 inch ball was used originally. The "H" scale with a 60 kilogram load and a 1/8 inch ball was added for softer specimens. B and H scale readings were taken on all specimens. All hardness determinations that exhibited excessive anvil effect and scatter between readings were eliminated from inclusion in this report. The hardness readings in each determination varied no more than 2.5 numbers for each value presented in this report.

EXPERIMENTAL RESULTS

Preparation of the experimental results consisted of:

(1) Determining the mechanical properties from tensile and hardness test data and listing of the results of each test in a logical tabular form.

(2) Comparing the tensile properties of material subjects to the various exposure and testing conditions with the room temperature tensile properties of material from the same panel in the "as received" condition, expressing the comparison in terms of "percent of room temperature properties" and listing a summarization of this data in a logical tabular form.

(3) Plotting summarized tensile properties versus exposure time for various exposure temperatures and testing temperatures.

(4) Plotting summarized tensile properties versus exposure temperatures for various exposure times and testing temperatures.

(5) Plotting the average hardness value of each specimen tensile tested at room temperature versus tensile yield strength and tensile ultimate strength.

TABLE I

STRAIN CALIBRATION DATA

Extensometer Displacement (1) in./in.	Autographic Recorder Strain Error Separate Calibrations in./in.			Maximum Error Percent
	PS5M EXTENSOMETER			
	1	2	3	
0.001000	.00006	.00002	.00002	8.0
0.002000	.00013	.00003	.00002	6.5
0.003000	.00022	-.00002	-.00004	7.3
0.004000	.00029	-.00008	-.00007	7.2
0.005000	.00034	-.00010	-.00008	6.8
0.006000	.00039	-.00012	-.00007	6.5
0.008000	.00054	-.00010	-.00012	6.7
	PSH-8MS EXTENSOMETER			
	1	2	3	
0.001000	.00003	-.00010	-.00008	10.0
0.002000	-.00002	-.00014	-.00009	7.0
0.003000	-.00004	-.00013	-.00020	6.7
0.004000	-.00007	-.00014	-.00021	5.2
0.005000	-.00006	-.00018	-.00009	3.6
0.006000	-.00006	-.00021	-.00016	3.5
0.008000	-.00012	-.00026	-.00020	3.3

(1) Extensometer displacement was measured by the difference in length of successive Pratt and Whitney Calibrated Gage Block stacks from a fixed reference plane.

TABLE II

LOAD CALIBRATION DATA
5000 LB., CAPACITY TEST MACHINE

Actual Load Lbs.	Load Indicator Error Separate Calibrations, Lbs.		Maximum Error Percent
	1	2	
100	0.0	0.0	0.00
150	0.0	0.0	0.00
200	1.7	-0.8	0.85
300	-2.0	-2.0	0.66
400	1.6	-2.5	0.62
450	0.4	0.4	0.09
600	-3.6	-5.2	0.87
800	1.8	-6.0	0.75
980	-9.0	-9.5	0.97
1000	-5.2	1.7	0.52
2000	9.7	7.1	0.48
2500	6.0	5.5	0.24

Actual Load Lbs.	Autographic Recorder Load Error Separate Calibrations, Lbs.						Maximum Error Percent
	1	2	3	4	5	6	
100	-0.8	0.2	-2.8	---	---	---	2.8
150	8.7	-0.1	-0.2	-1.0	1.5	0.5	5.8
200	1.1	1.9	-1.4	1.7	1.2	---	0.9
300	6.3	-0.8	-3.0	-3.0	---	---	2.1
400	1.6	1.4	1.1	-1.5	---	-0.1	0.4
450	8.1	1.0	-1.0	-4.0	0.9	0.4	1.8
600	1.8	-3.2	-5.0	-8.8	-3.5	-6.7	1.5
800	-4.8	-5.1	-3.1	-2.8	---	---	0.6
980	-13.0	-3.7	-10.0	-10.5	---	---	1.3
1000	-5.6	-0.9	-10.0	-16.0	-5.2	-6.5	1.6
2000	10.3	5.0	-5.0	11.6	10.1	---	0.9
2500	2.0	-1.5	-1.5	0.0	3.2	---	0.1

Mechanical Properties Determination

The mechanical properties determined during tensile testing were:

(a) Modulus of elasticity.

(b) Proportional limit.

(c) Yield strength (0.2% offset).

(d) Ultimate strength.

(e) Total elongation after fracture.

The modulus of elasticity is the slope or tangent of the secondary modulus portion of the load-strain record, divided by the original cross-sectional area of the tensile specimen. The proportional limit is the upper load at which the secondary modulus deviated from a straight line, divided by the original cross-sectional area of the specimen. The yield strength is the load intercept with the load-strain curve of a line having the same slope as the secondary modulus but offset from it to the right by 0.2% strain, divided by the cross-sectional area of the specimen.

Since the materials for this program were alclad aluminum alloys, both primary and secondary modulus slopes were present within the elastic region of the load-strain autographic records. The secondary modulus slope was chosen for determining the modulus of elasticity, proportional limit and yield strength for two reasons. For the majority of the tests the secondary modulus line was the longer, i.e. from one-half to four-fifths of the elastic portion of the load-strain graph. This longer line presented the possibility of a more accurate determination of the modulus, proportional limit and yield. On the other hand, the load-strain graphs characteristically often contained deviations or irregularities near the beginning of the curves which masked a true determination of these properties.

Another characteristic of the load-strain graphs, made it extremely difficult to determine a modulus slope, i.e. those tests of long time and high temperature exposures often resulted in load-strain graphs that continuously decreased in slope with increasing strain. In this case, any short flat portion of the curves that corresponded fairly well with a typical secondary modulus for the material were utilized to represent it.

As the result of the characteristics described above which tended to prevent determination of the true modulus slope and since the load and strain errors of the autographic records (see Tables I and II) are large enough to cause considerable error in the determination of the modulus of elasticity, this property should be considered as an approximation only. However, the yield strength shows little error with relatively large changes in the modulus slope since the slope of the curves at the yield intercept is sufficiently small that the load shows little change with variation of location of intercept.

The ultimate strength is the maximum load each specimen withstood prior to fracture, divided by the original cross-sectional area of the specimen. The percent elongation after fracture is one hundred times the difference in the length between two gage marks before test and after fracture divided by the gage mark length before test.

Tabulated Data

The tabulated data is presented as an appendix on pages 151 through 197. These data are presented in two types of tables. First, a series of tables presenting the complete tensile test results of each test specimen have been prepared. These Tables XXIII through XXXIV also average the results of the three or more individual tests of each alloy and test condition. Results of three tests are presented for each alloy and test condition, except where test results have been deleted because of exposure or testing difficulties and the consequent unreliable data. For this exception, these tensile properties that were reliable from the original three specimens are presented along with the test results of additional specimens to fill-in the missing properties on the first three specimens.

The final tabulation of data, consisting of Tables XVII through XX in the appendix, summarizes the tensile properties for each alloy and test condition. In these tables the tensile properties are presented for each alloy and test condition as the "average percent of room temperature properties". Each value in the table is obtained by calculating the percent ratio of the mechanical properties of each test specimen to the room temperature mechanical properties of the "no exposure" or "stock control" specimens from the same panel and then averaging the percent ratios that represent each discrete alloy and test condition. This non-dimensional procedure was utilized to eliminate the normal variation in mechanical properties of the materials from these summarized data tables.

Hardness versus tensile properties test data are also presented in Tables XXI and XXII for all tensile specimens tested at room temperature.

Graphical Data

A graphical presentation of the summarized tensile properties of each alloy and test condition is shown in Figures 24 through 103 of the appendix. These graphs include plots of percent of room temperature tensile properties versus exposure time and percent of room temperature tensile properties versus exposure temperature for each tensile property, alloy and test temperature.

Hardness versus yield strength and hardness versus ultimate strength graphs are presented in Figures 104 through 111 for both Rockwell hardness scales and both alloys.

ANALYSIS OF RESULTS

The test data presented in this report present over seventy test conditions for each of the materials investigated, 7075-T6 Alclad sheet and 2024-T3 Alclad sheet. These data present a challenge to develop general expressions which will most advance the knowledge of the elevated temperature properties of these aluminum alloys which are the ones most commonly used in airframes.

The alloys tested, 7075-T6 and 2024-T3, have been known to suffer from onver-aging when exposed to elevated temperatures. They suffer doubly from elevated temperature. Therefore, it is necessary to know the time spent at temperature as well as the temperature in order to evaluate the strength properties of these materials. But seldom is a service condition so simple as a given time at one temperature. Therefore, it is desirable to be able to predict the remaining strengths of these materials at any temperature, within the temperature range providing usable strength, after they have been exposed to any sequence of various exposure times at various temperatures.

Analysis of Basic Data

The basic test data consist of various single exposures (specimens exposed to one temperature for a given time), then pulled as tensile coupons at room temperature, 200°F, 300°F, and 400°F. Data thus obtained include maximum elongation in 2 inches, modulus of elasticity, and proportional limit, but only the ultimate tensile stress and the tensile yield stress data have been analyzed as these are the mechanical properties which provide load carrying ability.

A semi-empirical analysis was utilized as no generally accepted analytical method is known to exist at this time. The analysis is built upon the rate-process theory which has been applied to such diverse processes as creep, tempering, and diffusion of metals and offers a known method of combining temperature and time to obtain a single parameter by which can be measured the degree of an exposure condition. This theory expresses the rate at which a process takes place as $r = Ae^{-Q/RT}$, where A is a constant, Q is the activation energy for the material and process, R is the gas constant and T is the absolute temperature. A simple time-temperature parameter has been derived from the rate-process theory by F.R. Larson and James Miller, and is published in Transactions of ASME, July 1952, page 765, "A Time-Temperature Relationship for Rupture and Creep Stresses". Their parameter has the form $T\,(C + \mathrm{LOG}_{10}\ t)$ .... where T is the absolute temperature in degrees Rankine and t is the time in hours. Preliminary plotting of the test data vs. $T_{°R}\,(20 + \mathrm{LOG}_{10}\ t)$ gave excessive scatter and was therefore modified empirically to provide a more accurate analysis.

a) Analysis of the Ultimate Tensile Stress of 7075-T6 Alclad Sheet

The ultimate tensile stress data of 7075-T6 clad sheet were first plotted as percent of room temperature ultimate tensile stress versus the Larson-Miller time-temperature parameter, $\theta = T_{oR}\ (20 + \mathrm{LOG}_{10}\ t_{hr.})$

This procedure resulted in only fair resulution of test points, and the plots are shown on Figure 12 for the four test temperatures, (R.T., 200°F, 300°F, and 400°F). It was observed that the longer times for a given θ are more severe in reducing F_{tu} than the shorter time (times indicated on Figure 12). No theoretical reason for this has been determined; however, as a second step an empirical adjustment of θ was made. This resulted in a modification of time by the 1.46 power in the time-temperature parameter, θ, to give $\theta' = T_{oR}\ (20 + 1.46\ \mathrm{LOG}_{10}\ t_{hr.})$. This modified Larson-Miller time-temperature parameter provides much better agreement with the test data as is readily apparent in Figure 13 where the percent of room temperature ultimate tensile stress of 7075-T6 clad sheet is plotted against θ', the modified time-temperature parameter. The statistical analysis given in Table IV shows that the curves of Figure 13 fit the data within plus or minus 4.7% of room temperature ultimate stress for approximately 95% of the tests. (Between $\pm 2\delta_t$ are 95.5% of the test points for normal distribution.)

At this point the similarity of the curves of Figure 13 for the various test temperatures suggested the possibility of normalizing the data for the four test temperatures. This was successfully done by dividing the percent of room temperature ultimate stress values by the corresponding percentage for the 0.1 hour exposure at 300°F at each respective test temperature. The resulting normalized curve is presented in Figure 14. Analytical expressions for the curve have been determined as follows:

$$\theta \leq 16{,}580 \qquad R = 1.163\ e^{-0.00001071\theta'}$$

$$16{,}580 \leq \theta' \leq 20{,}230 \qquad R = 44.70\ e^{-0.00023\theta'}$$

$$20{,}230 \leq \theta' \qquad R = .421$$

R = The decimal fraction of the no exposure ultimate tensile stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ'.

The 0.1 hour exposure at 300°F was chosen as the basis for normalizing the test data versus θ' because it represents the minimum exposure as measured by θ'. It was assumed that this 0.1 hour at 300°F exposure does not affect the ultimate tensile stress of 7075-T6 clad sheet and thus the ultimate tensile stress at the test temperatures are assumed to represent the ultimate tensile stresses after <u>no</u>

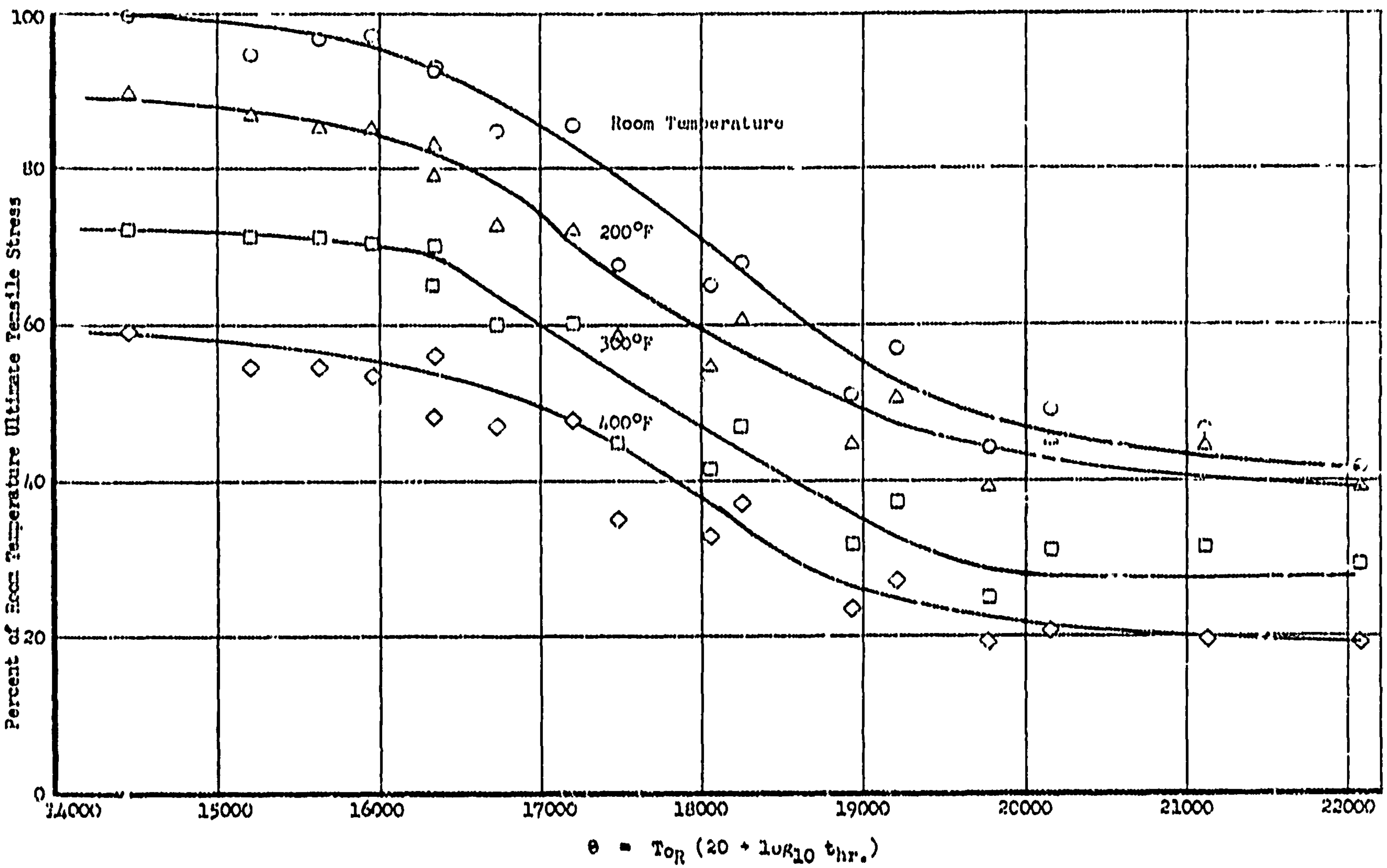


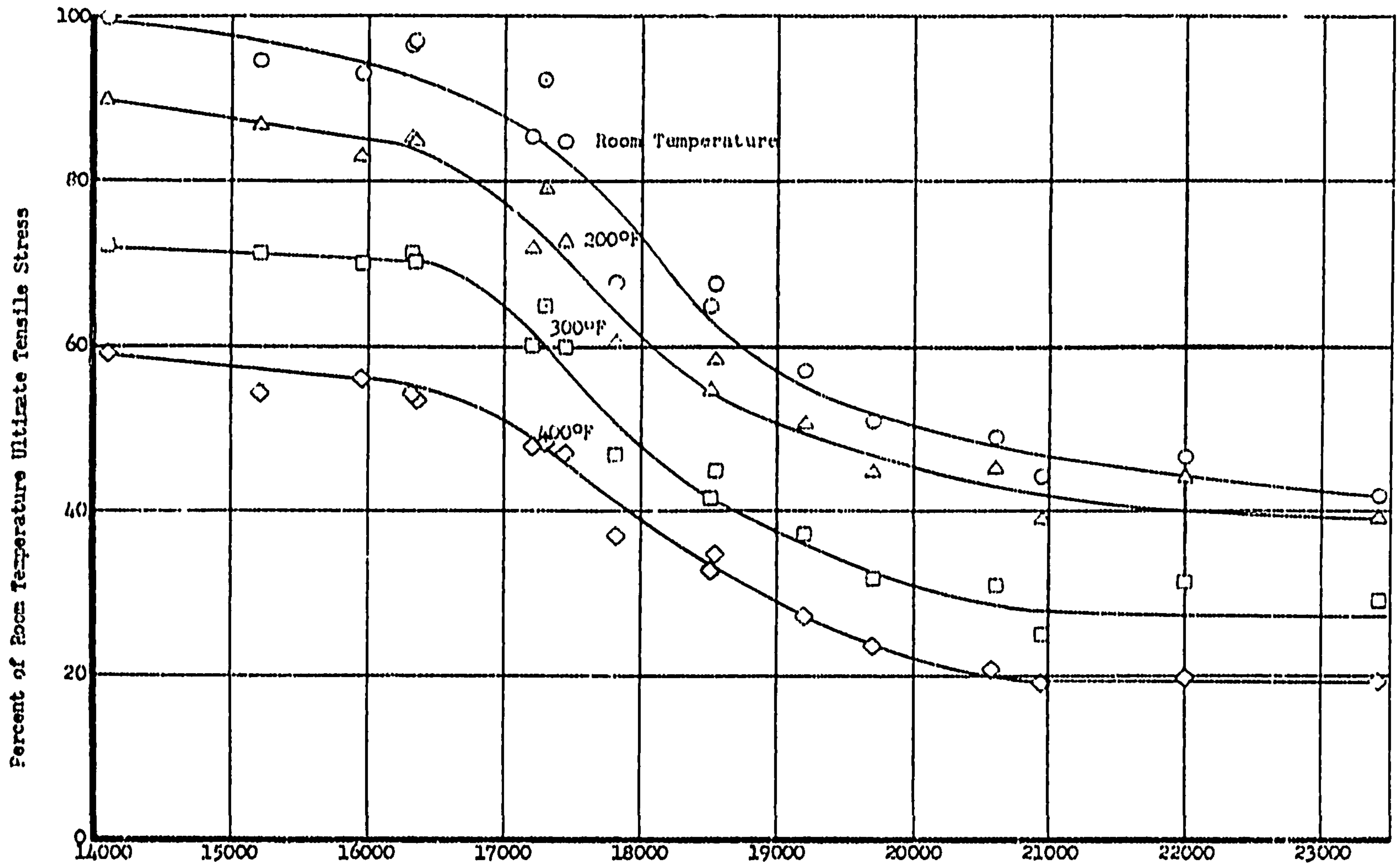
Figure 12. Percent of Room Temperature Ultimate Tensile Stress of 7075-T6 Alclad versus Time-Temperature Parameter, $\theta = T_{^\circ R}\,(20 + \log_{10} t_{hr.})$ for Test Temperatures of Room Temperature, 200°F, 300°F, and 400°F.

TABLE III

MODIFIED LARSON-MILLER PARAMETER FOR 7075-T6 ALCLAD

$$\theta' = T_{or} (20 + 1.46 \text{ LOG}_{10} t_{hr.})$$

Exposure Temperature °F	Exposure Time, Hour	Modified Larson-Miller Parameter	Exposure Temperature °F	Exposure Time, Hour	Modified Larson-Miller Parameter
300	0.1	14,090	300	1000	18,530
300	1	15,200	500	1	19,200
400	0.1	15,940	600	0.1	19,650
250	100	16,270	400	100	19,710
300	10	16,310	500	10	20,600
400	1	17,200	400	1000	20,970
250	1000	17,310	600	1	21,200
300	100	17,420	500	100	22,000
500	0.1	17,800	600	10	22,750
400	10	18,460	500	1000	23,400



$\theta' = T_{oR}\,(20 + 1.46 \log_{10} t_{hr.})$

Figure 13. Percent of Room Temperature Ultimate Tensile Stress of 7075-T6 Alclad versus Modified Time - Temperature Parameter, $\theta' = T_{oR}\,(20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE IV

STATISTICAL ANALYSIS OF ULTIMATE TENSILE
STRESS OF 7075-T6 ALCLAD versus θ'

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
8	1	4	16	25	4	16	25
6	3	3	9	16	9	27	48
4	6	2	4	9	12	24	54
2	15	1	1	4	15	15	60
0	26	0	0	1	0	0	26
-2	11	-1	1	0	-11	11	0
-4	2	-2	4	1	- 4	8	2
S	64				25		
SS						101	215
S^2/n						10	124
SSD						91	91
Sw^2						1.443	
Sw						1.20	
S/n					.391		

$$\bar{t} = 2\ (.391) = .782$$

$$St = 2\ (1.20) = 2.40$$

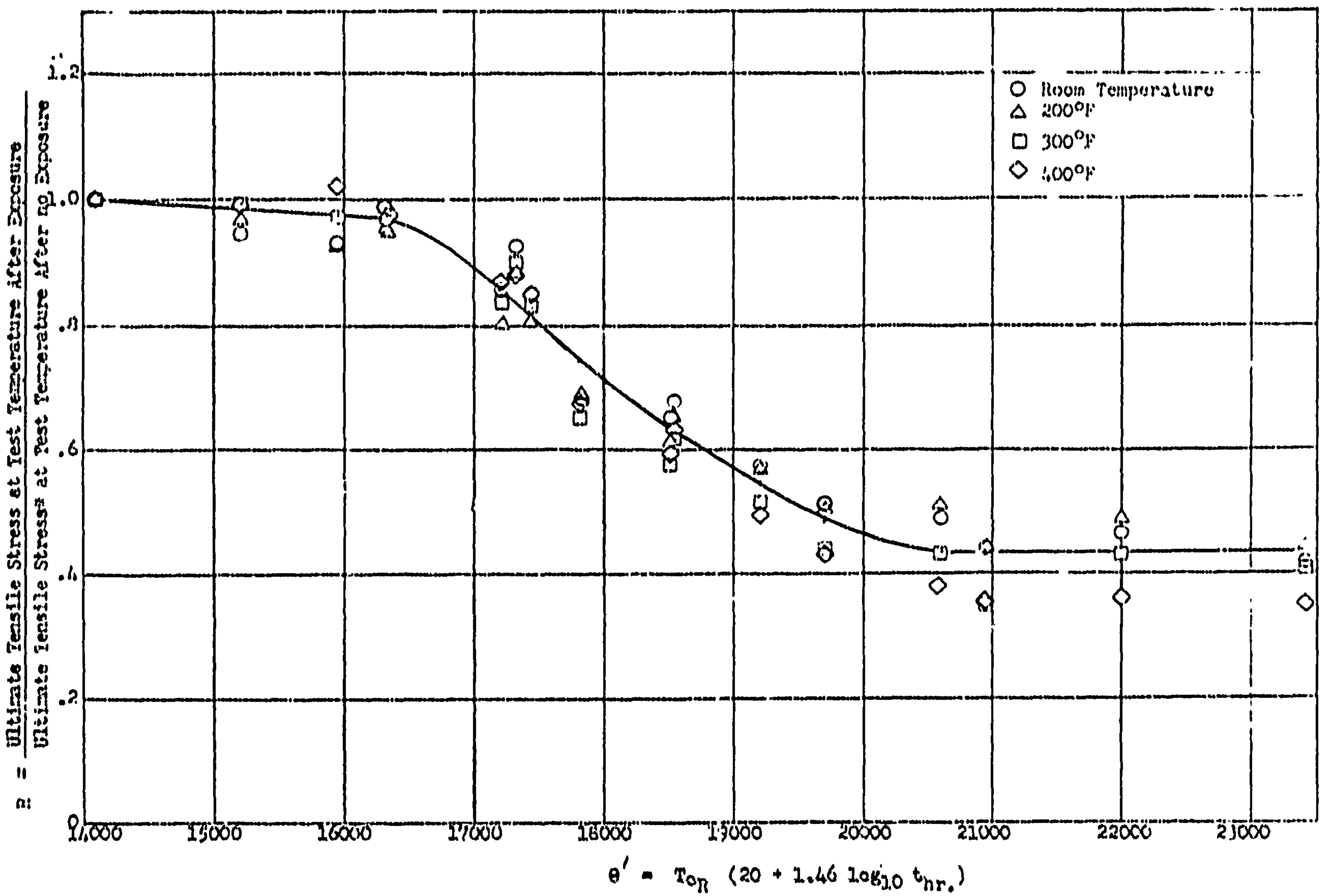


Figure 14. Ratio of Ultimate Tensile Stress of 7075-T6 Clad Sheet at Test Temperature After Exposure to Ultimate Tensile Stress* of 7075-T6 Clad Sheet at Test Temperature After no Exposure Versus Modified Time-Temperature Parameter, $\theta' = T_{^\circ R}\ (20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.

* F_{tu} at Test Temperature after 0.1 hr., 300°F exposure.

exposure. Tests were run with no exposure which verify this assumption as indicated by the tabulated results below. The maximum difference of 2.9% is well within the scatter of the material itself.

Test Temperature	% R.T. Ultimate Tensile Stress 7075-T6	
	0.1 hour at 300°F	No Exposure
R.T	99.7	100
200°F	89.7	91.1
300°F	72.1	75.0
400°F	55.0	55.2

The statistical analysis given in Table V shows that the normalized curve fits approximately 95% of the test data within plus or minus 8% of the room temperature ultimate tensile stress.

b) Analysis of the Tensile Yield Stress of 7075-T6 Alclad Sheet

The tensile yield stress data of 7075-T6 clad sheet were first plotted as percent of room temperature tensile yield stress versus the Larson-Miller time-temperature parameter, $\theta = T_{R} (20 + 1.46 \; LOG_{10} \; t_{hr.})$. This procedure produced results similar to the results of the ultimate tensile stress in that only fair correlation was obtained. As with the ultimate tensile stress data, much better consistency is obtained by using the modified Larson-Miller time-temperature parameter, $\theta' = T_{oR} (20 \;\; 1.46 + LOG_{10} \; t_{hr.})$. The percent of room temperature tensile yield stress for 7075-T6 clad sheet has been plotted against θ' in Figure 15. The statistical analysis of the correlation achieved in Figure 15 is given in Table VI and indicates that 95% of the data are within 4.72 percent of room temperature tensile yield stress of the respective curves.

The plots in Figure 15 cannot be nearly so easily normalized as that of the ultimate tensile stress. This is due to the tensile yield stress of 7075-T6 clad sheet becoming less temperature dependent with increasing degree of exposure as measured by θ'. Generalization warrants the utilization of a fairly complicated normalization procedure. Therefore, normalization was accomplished by dividing the percent of room temperature tensile yield stress at the test temperature at exposure $\theta' = 14{,}090$ by the percent of room temperature tensile yield stress after 0.1 hour at 300°F. This provides the desired normalization at $\theta' = 14{,}090$. Then the divisor is varied linearly with θ' to provide no normalization at $\theta' = 32{,}690$. The value of 32,690 is off the abscissa, but is the value required to provide good normalization. Mathematically this is expressed as:

TABLE V

STATISTICAL ANALYSIS OF NORMALIZED ULTIMATE TENSILE STRESS OF 7075-T6 ALCLAD versus θ'

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
8	2	4	16	25	8	32	50
6	3	3	9	16	9	27	48
4	6	2	4	9	12	24	54
2	9	1	1	4	9	9	36
0	20	0	0	1	0	0	20
-2	8	-1	1	0	-8	8	0
-4	6	-2	4	1	-12	24	6
-6	9	-3	9	4	-27	81	36
-8	5	-4	16	9	-20	80	45
S	68				-29		
SS						285	295
S^2/n						12	22
SSD						273	273
S_w^2						4.075	
S_w						2.02	
S/n					-.427		

$$\bar{t} = 2\,(-.427) = -\,.853$$

$$S_t = 2\,(2.02 \quad = 4.04$$

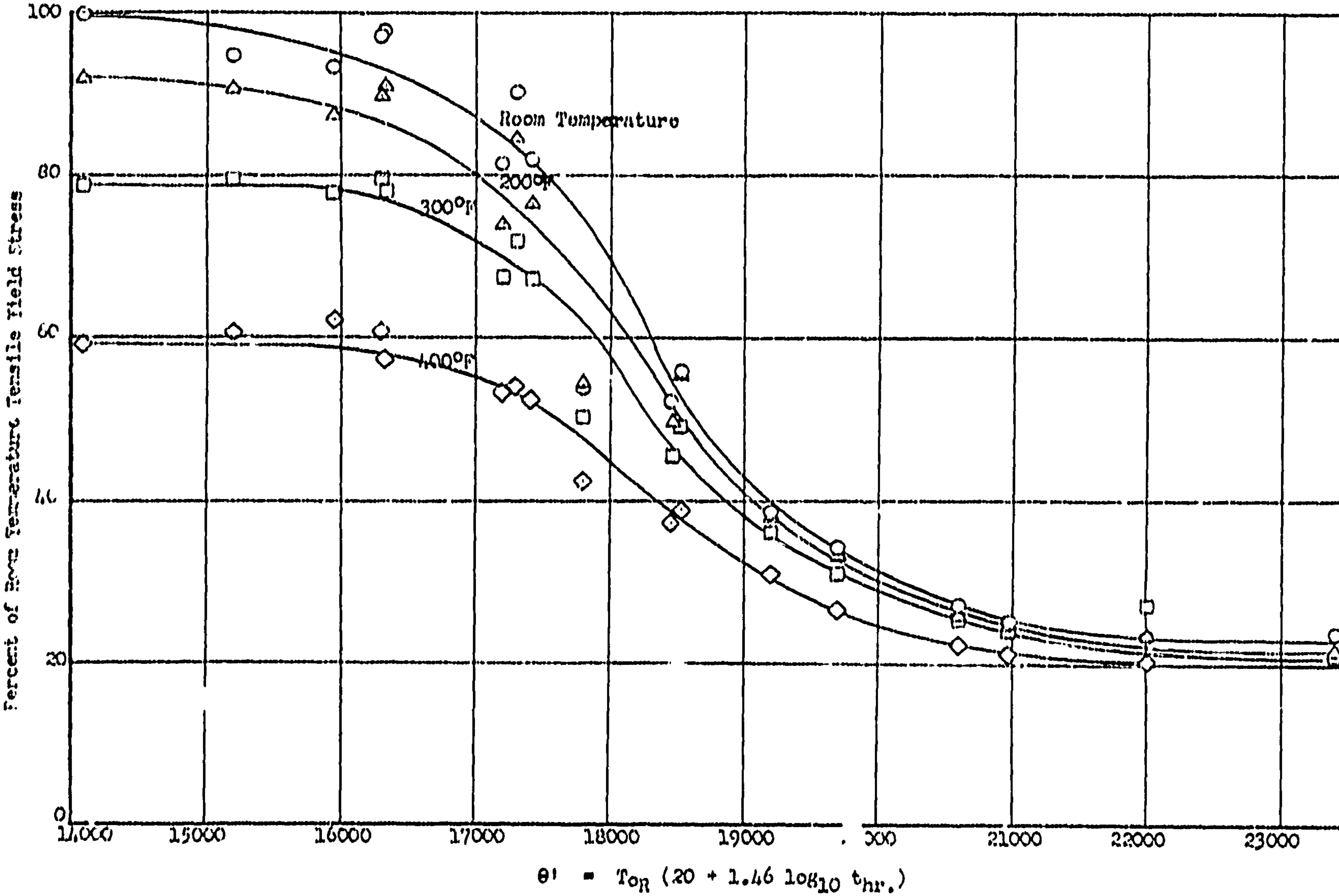


Figure 15. Percent of Room Temperature Tensile Yield Stress of 7075-T6 Alclad versus Modified Time - Temperature Parameter, $\theta' = T_{°R}\,(20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE VI

STATISTICAL ANALYSIS OF TENSILE YIELD STRESS OF 7075-T6 ALCLAD versus θ'

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
8	1	4	16	25	4	16	25
6	2	3	9	16	6	18	32
4	8	2	4	9	16	32	72
2	7	1	1	4	7	7	28
0	37	0	0	1	0	0	37
-2	5	-1	1	0	-5	5	0
-4	2	-2	4	1	-4	8	2
-6	1	-3	9	4	-3	9	4
S	63				21		
SS						95	200
S^2/n						7	112
						88	88
SSD							
Sw^2						1.419	
Sw						1.19	
S/n					.333		

$$\bar{t} = 2\,(.333) = .667$$

$$S_t = 2\,(1.19) = 2.38$$

$$R = \frac{x}{y + (100-y)\left(\frac{\theta' - 14{,}090}{18{,}600}\right)}$$

where R = The decimal fraction of the no exposure tensile yield stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ'.

x = The percent of room temperature tensile yield stress at the test temperature after being exposed to elevated temperature.

y = The percent of room temperature tensile yield stress at the same test temperature as for x after having been exposed to 0.1 hour at 300°F.

θ' = The modified Larson-Miller parameter $\theta' = T_{oR}(20 + 1.46 \, LOG_{10} \, t_{hr.})$ calculated for the exposure condition which determined x.

As with the ultimate tensile stress data, the 0.1 hour at 300°F exposure was assumed to be the same as no exposure. This assumption is not quite so good for the tensile yield stress data as for the ultimate tensile stress data, but does not invalidate the assumption. The tensile yield stress data are presented below for the 0.1 hour at 300°F exposure and no exposure. The biggest discrepancy is seen to be 5% at the 300°F test temperature.

Test Temperature	% R.T. Tensile Yield Stress	
	0.1 hour at 300°F	No Exposure
R.T.	99.8	100
200°F	92.0	96.5
300°F	78.8	83.8
400°F	59.2	60.1

Analytical expressions for the normalized curve of tensile yield stress data for 7075-T6 Alclad sheet have been determined as follows:

$\theta' \leq 16{,}700$ $\qquad R = 1.27 \, e^{-0.0000167\theta'}$

$16{,}700 \leq \theta' \leq 20{,}400$ $\qquad R = 223.3 \, e^{-0.000327\theta'}$

$20{,}400 \leq \theta'$ $\qquad R = 1.541 \, e^{-0.0000828\theta'}$

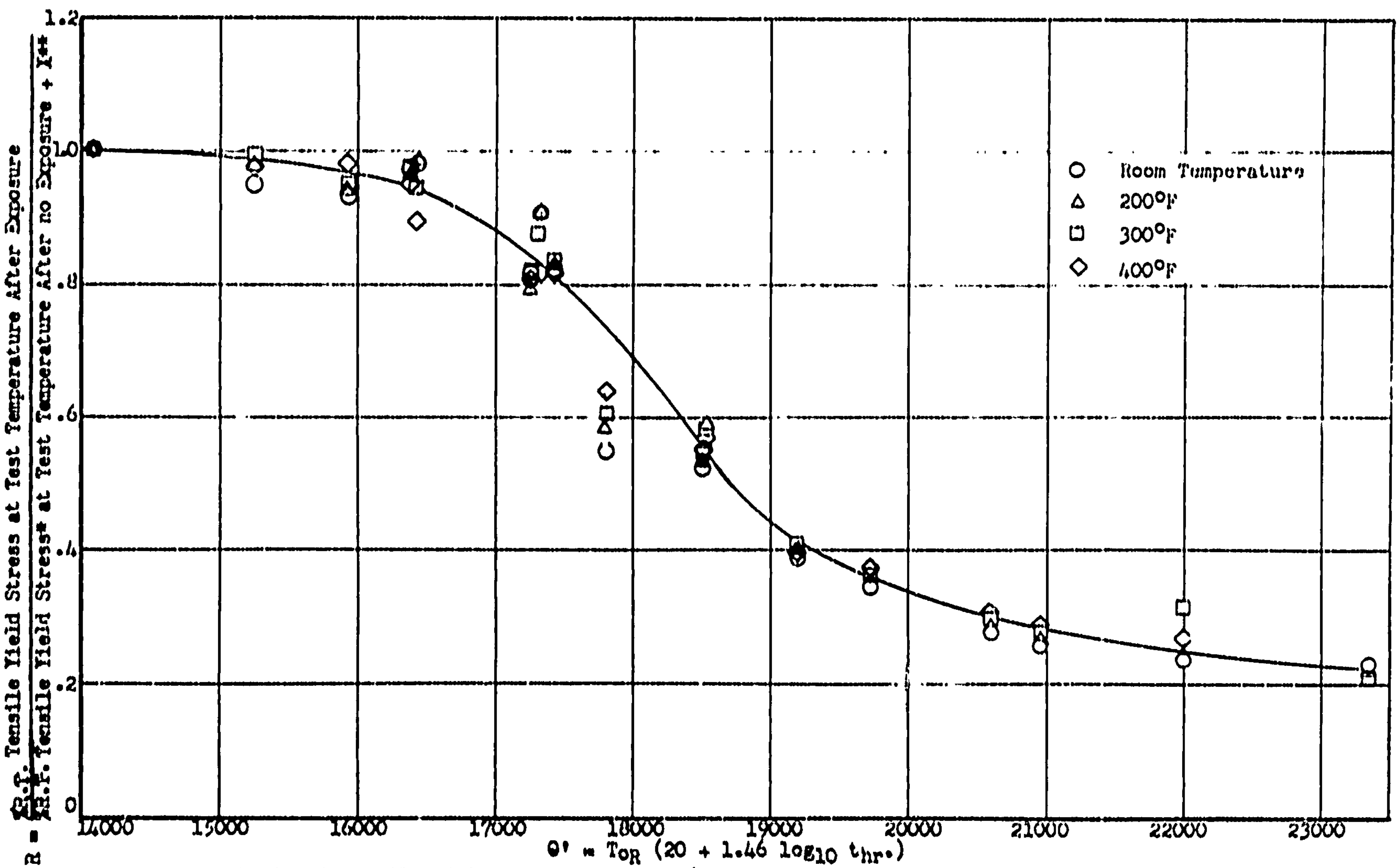


Figure 16. Ratio of Tensile Yield Stress of 7075-T6 Clad Sheet at Test Temperature After Exposure to Tensile Yield Stress* of 7075-T6 Clad Sheet at Test Temperature After no Exposure + X** Versus Modified Time-Temperature Parameter, $\Theta' = T_{°R}\,(20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.

* F_{ty} at Test Temperature after 0.1 hr., 300°F exposure.

** $X = (100 - \%\ \text{R.T.}\ F_{ty}\ \text{at}\ °F,\ \text{no exposure})\left(\frac{\Theta' - 14,090}{18,600}\right)$

TABLE VII

STATISTICAL ANALYSIS OF NORMALIZED TENSILE YIELD STRESS OF 7075-T6 ALCLAD versus θ'

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
7.5	2	5	25	36	10	50	72
6.0	2	4	16	25	8	32	50
4.5	0	3	9	16	0	0	0
3.0	1	2	4	9	2	4	9
1.5	11	1	1	4	11	11	44
0	13	0	0	1	0	0	13
-1.5	11	-1	1	0	-11	11	0
-3.0	5	-2	4	1	-10	20	5
-4.5	2	-3	9	4	-6	18	8
-6.0	1	-4	16	9	-4	16	9
-7.5	3	-5	25	16	-15	75	48
-9.0	0	-6	36	25	0	0	0
-10.5	0	-7	49	36	0	0	0
-12.0	1	-8	64	49	- 8	64	49
S	52				-23		
SS						301	307
S^2/n						10	16
SSD						291	291 Chk.
S_w^2						5.71	
S_w						2.39	
S/n					-.442		

$$\bar{t} = 1.5\ (-.442) = -.663$$

$$S_t = 1.5\ (2.39 \quad = 3.50$$

The curve so defined fits the tests points within 7% approximately 95% of the time. This method provides slightly greater accuracy for tensile yield stress of 7075-T6 alclad sheet than that for the ultimate tensile stress of 7075-T6 alclad sheet.

c) Analysis of the Ultimate Tensile Stress of 2024-T3 Alclad Sheet

First, the percent of room temperature ultimate tensile stress data of 2024-T3 alclad sheet were plotted against the Larson-Miller time temperature parameter, $\theta = T_{oR} + LOG_{10}\ t_{hr.})$. As with the 7075-T6 data, this parameter was found lacking the desired degree of correlation. Next, the percent of room temperature ultimate tensile stress data of 2024-T3 were plotted versus the modified Larson-Miller parameter, $\theta' = T_{oR}\ (20 + 1.46\ LOG_{10}\ t_{hr.})$ on Figure 17. Disappointingly, θ' does not provide the desired fit to the experimental points as is apparent in Figure 17. A statistical analysis was made to check the general usefulness of θ' and it is presented in Table VIII. This analysis includes the test data for both 7075-T6 and 2024-T3, ultimated and yield stresses. The results indicated that θ' is very marginal as to general ability to fit the test data for both properties of both materials. As θ' provided an acceptable fit for 7075-T6 property data, it was concluded that θ' does not fit the 2024-T3 test data satisfactorily. This led to another modification of the Larson-Miller parameter.

Study of the results achieved utilizing θ and θ' indicated that the desired modification of θ which would prove satisfactory for 2024-T3 test data must be some compromise of θ and θ'. The modification of θ which was determined to best fit the 2024-T3 test data is $\theta'' = T_{oR}\ (20 + 1.3\ LOG_{10}\ t_{hr.})$. The plot of the percent of room temperature ultimate tensile stress data for 2024-T3 alclad sheet against $\theta'' = T_{oR}\ (20 + 1.3\ LOG_{10}\ t_{hr.})$ is presented in Figure 18. The statistical analysis of this plot is presented in Table X and reveals that approximately 95% of test points lay within 6% of the respective curves.

The first effort towards normalization of the ultimate tensile stress data of 2024-T3 was straight normalization. That is, the percent of room temperature ultimate tensile stress at temperature X after exposure Y is divided by the percent of room temperature ultimate tensile stress at temperature X after 0.1 hour exposure at 300°F. The results of such a normalization procedure indicated that the test points at smaller θ'' values were not normalized enough and at larger θ'' values the test points were normalized too much. Therefore, the ultimate tensile stress data of 2024-T3 were normalized about $\theta'' = 17{,}200$ with the results as shown in Figure 19. Mathematically, this normalization is written as:

$$R = \frac{X}{y - (100-y)\left(\frac{17{,}200 - \theta''}{8730}\right)}$$

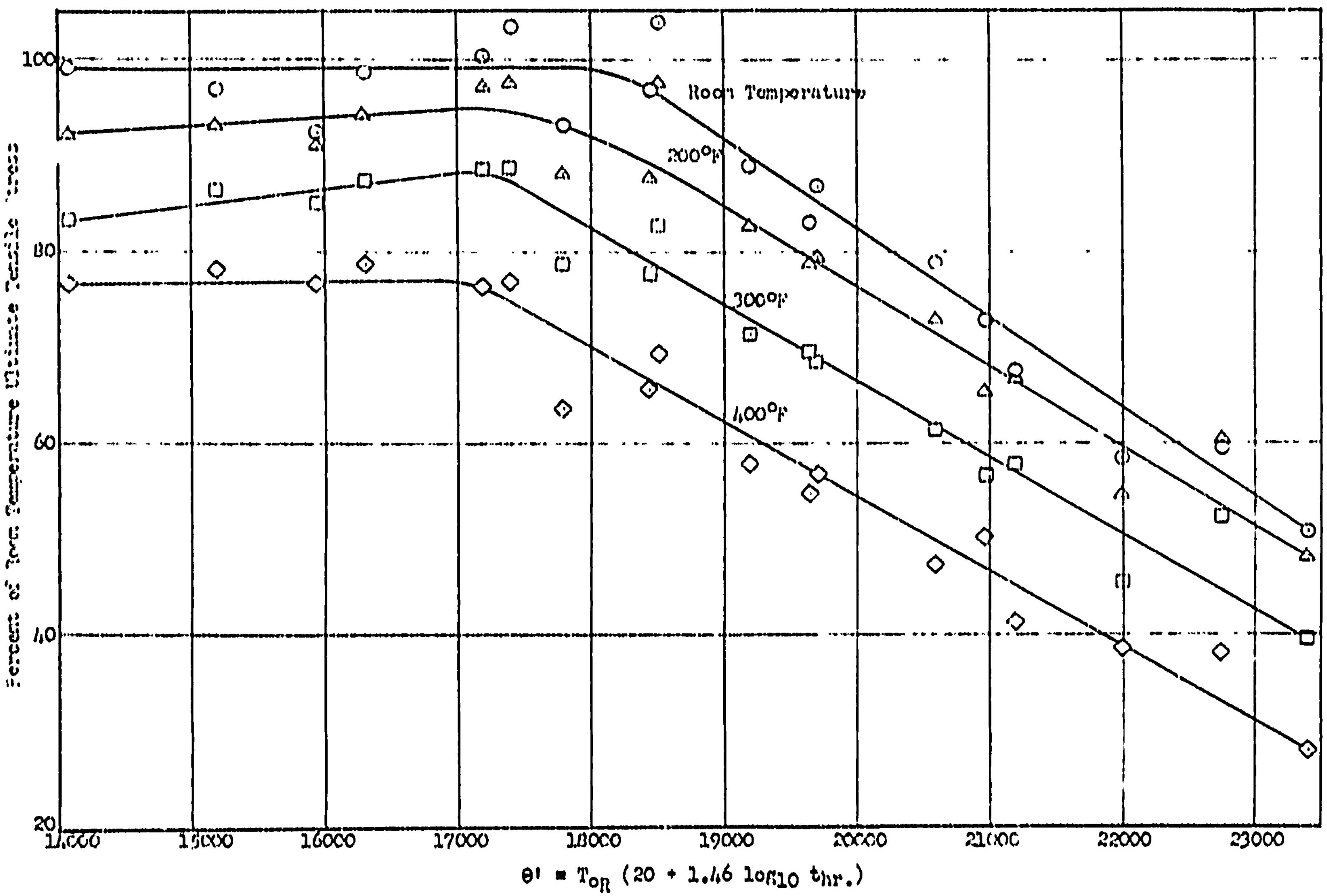


Figure 17. Percent of Room Temperature Ultimate Tensile Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter, $\theta' = T_{^\circ R}\,(20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE VIII

STATISTICAL ANALYSIS OF ULTIMATE TENSILE STRESS AND TENSILE YIELD STRESS OF 7075-T6 AND 2024-T3 VERSUS $\theta' = T_{o_r}(20 + 1.36 \log_{10} t_{hr.})$

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
12	1	6	36	49	6	36	49
10	4	5	25	36	20	100	144
8	7	4	16	25	28	112	175
6	11	3	9	16	33	99	176
4	29	2	4	9	58	116	261
2	45	1	1	4	45	45	180
0	103	0	0	1	0	0	103
-2	43	-1	1	0	-43	43	0
-4	9	-2	4	1	-18	36	9
-6	8	-3	9	4	-24	72	32
-8	6	-4	16	9	-24	96	54
-10	1	-5	25	16	-5	25	16
-12	5	-6	36	25	-30	180	125
-14	2	-7	49	36	-14	98	72
-16	3	-8	64	49	-24	192	147
-18	0	-9	81	64	0	0	0
-20	1	-10	100	81	-10	100	81
S	278	-34			- 2		
SS						1350	1624
S^2/n						0	274
SSD						1350	1350
S_w^2						4.86	
S_w						2.21	
S/n					.00719		

$$\bar{t} = 2(.00719) = .01438$$

$$S_t = 2(2.21) = 4.42$$

TABLE IX

Modified Larson-Miller Parameter for 2024-T3 Alclad, $\theta' = T_{or} (20 + 1.3 \, LOG_{10} \, t_{hr.})$

Exposure Temperature °F	Exposure Time, Hour	Modified Larson-Miller Parameter	Exposure Temperature °F	Exposure Time, Hour	Modified Larson-Miller Parameter
300	.1	14,210	400	10	18,320
300	1	15,200	500	1	19,200
400	.1	16,080	400	100	19,440
300	10	16,190	600	.1	19,820
300	100	17,180	500	10	20,450
400	1	17,200	400	1000	20,550
500	.1	17,950	600	1	21,200
300	1000	18,160	500	100	21,700
			600	10	22,580
			500	1000	22,940

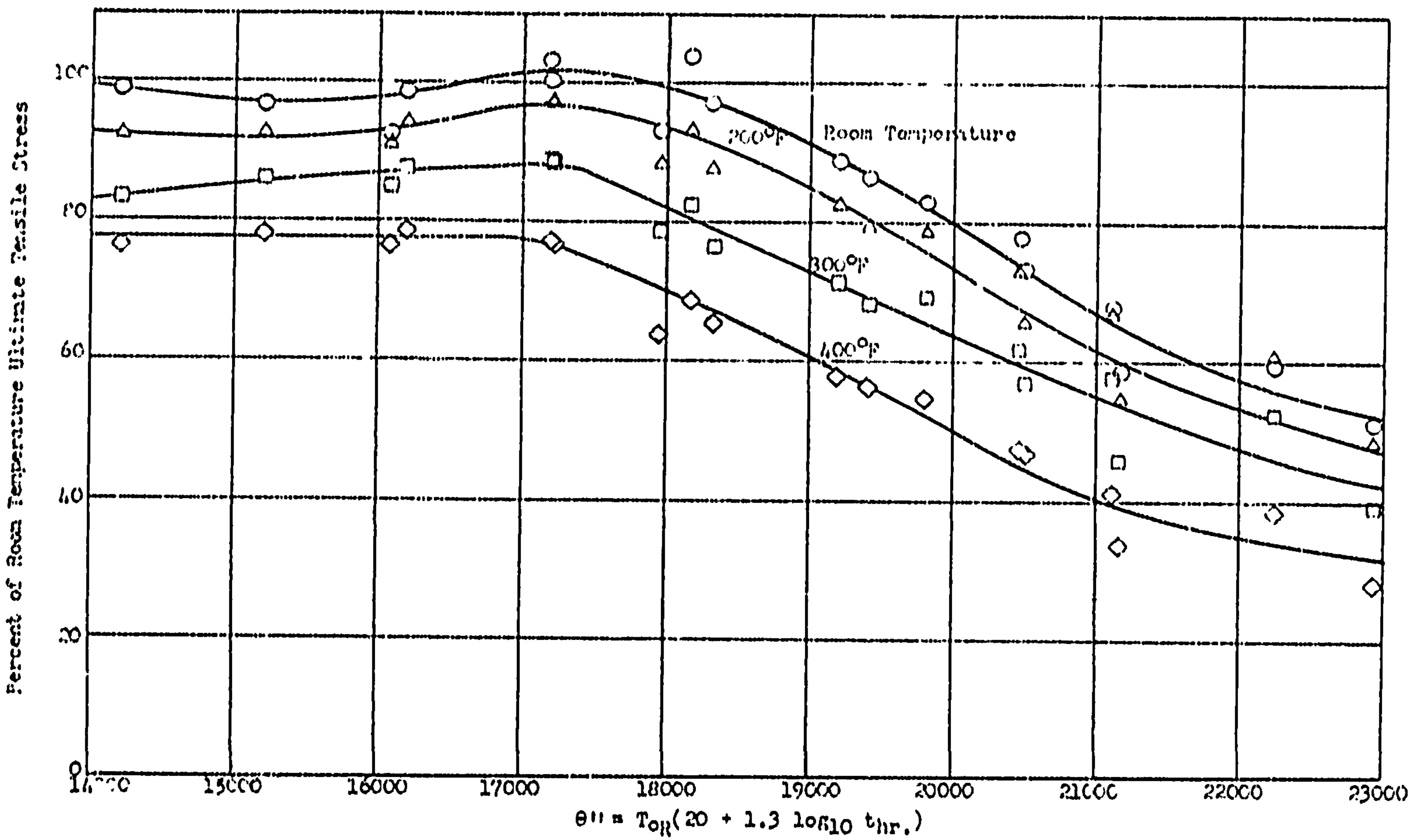


Figure 18. Percent of Room Temperature Ultimate Tensile Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter, $\theta'' = T_{oR} (20 + 1.3 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE X

STATISTICAL ANALYSIS OF ULTIMATE TENSILE STRESS OF 2024-T3 ALCLAD VERSUS θ''

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
9	1	9	81	100	9	81	100
8	0	8	64	81	0	0	0
7	0	7	49	64	0	0	0
6	2	6	36	49	12	72	98
5	2	5	25	36	10	50	72
4	2	4	16	25	8	32	50
3	3	3	9	16	9	27	48
2	8	2	4	9	16	32	72
1	9	1	1	4	9	9	36
0	20	0	0	1	0	0	20
-1	9	-1	1	0	-9	9	0
-2	4	-2	4	1	-8	16	4
-3	3	-3	9	4	-9	27	12
-4	2	-4	16	9	-8	32	18
-5	3	-5	25	16	-15	75	48
-6	2	-6	36	25	-12	72	50
-7	1	-7	49	36	-7	49	36
-8	1	-8	64	49	-8	64	49
S	72				-3		
SS						647	713
S^2/n						0	66
SCD						647	647
S_w^2						9.11	
$S_w = S_t$						3.02	
$S/n = \bar{t}$					-.04167		

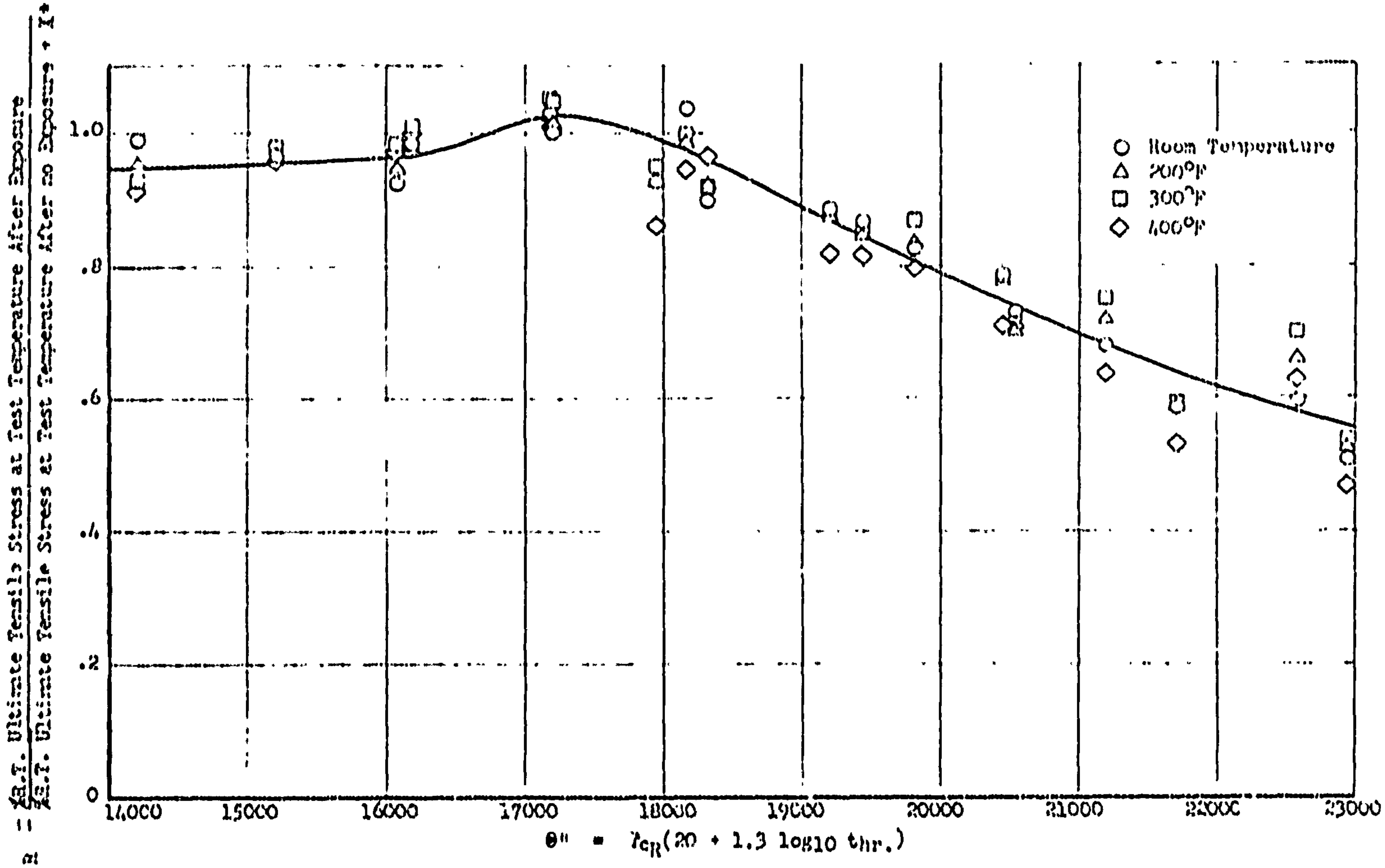


Figure 19. Ratio of Ultimate Tensile Stress of 2024-T3 Clad Sheet at Test Temperature After Exposure to Ultimate Tensile Stress of 2024-T3 Clad Sheet at Test Temperature After no Exposure *X* Versus Modified Time-Temperature Parameter, $\theta'' = T_{^\circ R}\,(20 + 1.3 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures

$$*X = (100 - \%\ R.T.\ F_{tu} \text{ at } ^\circ F, \text{ no exposure}) \left(\frac{17{,}200 - \theta''}{8730}\right)$$

TABLE XI

Statistical Analysis of Normalized Ultimate Tensile Stress of 2024-T3 Alclad Versus θ''

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
12	1	6	36	49	6	36	49
10	0	5	25	36	0	0	0
8	1	4	16	25	4	16	25
6	3	3	[illegible]	16	9	27	48
4	9	2	[illegible]	9	18	36	81
2	15	1	1	4	15	15	60
0	15	0	0	1	0	0	15
-2	9	-1	1	0	-9	9	0
-4	13	-2	4	1	-26	52	13
-6	3	-3	9	4	-9	27	12
-8	1	-4	16	9	-4	16	9
-10	1	-5	25	16	-5	25	16
-12	1	-6	36	25	-6	36	25
S	72				-7		
SS						295	353
S^2/n						1	59
SSD						294	294
Sw^2						4.14	
Sw						2.03	
S/n					-.0972		

$$\bar{t} = 2\,(-.0972) = -.1944$$

$$S_t = 2\,(2.03) = 4.06$$

where R = The decimal fraction of the no exposure ultimate tensile stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ''.

x = The percent of room temperature ultimate tensile stress at the test temperature after being exposed to elevated temperature.

y = The percent of room temperature ultimate tensile stress at the same test temperature as for x after no exposure.

θ'' = The modified Larson-Miller parameter $\theta'' T_{oR}$ (20 1.3 LOG_{10} $t_{hr.}$).

Only fair normalization was thus achieved, the range within which approximately 95% of the tests fall having been increased to 8% of the room temperature ultimate tensile stress.

In the first normalization, the assumption was made that 0.1 hour exposure at 300°F does not appreciably change the material properties. This assumption was satisfactorily checked by the no exposure tests as tabulated below.

Test Temperature	% R.T. Ultimate Tensile Stress 2024-T3	
	0.1 hour at 300°F	No Exposure
R.T.	99.1	100
200°F	92.4	95.25
300°F	83.4	84.5
400°F	76.6	75.6

The greatest difference exists at the 200°F test temperature and amounts to only 2.85% of room temperature ultimate tensile stress.

d) Analysis of the Tensile Yield Stress of 2024-T3 Alclad Sheet

As stated in (c) above, the tensile yield stress data of 2024-T3 was included in the analysis evaluating the modified Larson-Miller parameter $\theta'' T_{oR} (20 + 1.46 \, LOG_{10} \, t_{hr.})$. The plot of percent room temperature tensile yield stress against θ'' is presented in Figure 21. Again, as with the ultimate tensile stress data of 2024-T3 the parameter θ' does not give the desired agreement among the various exposures.

The modified Larson-Miller parameter $\theta'' = T_{oR} (20 + 1.3 \, LOG_{10} \, t_{hr.})$ gives better resolved curves than did θ'. The statistical analysis presented in Table III shows that the curves in Figure 22 are within 4% of approximately 95% of the test points.

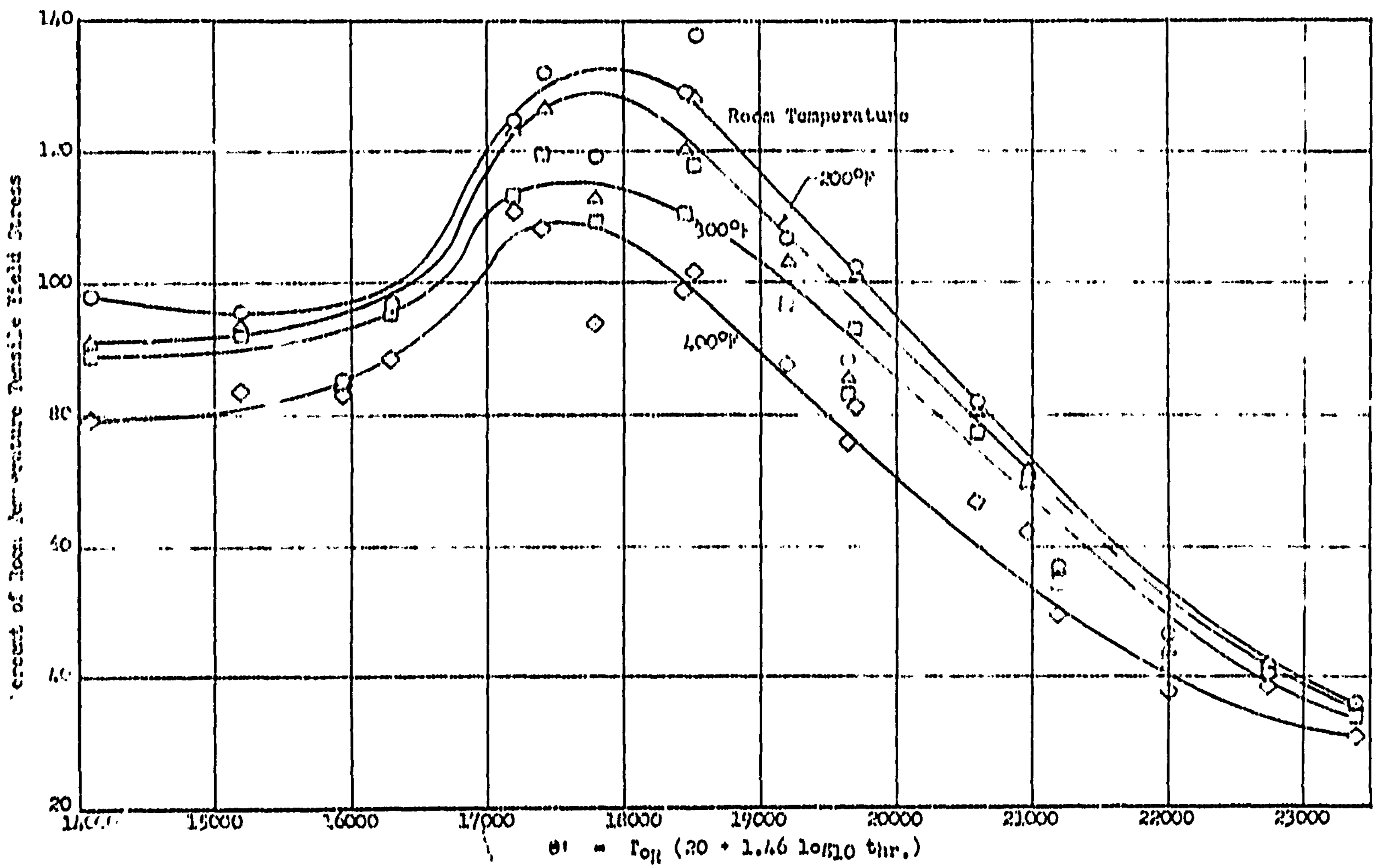


Figure 20. Percent of Room Temperature Tensile Yield Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter, θ' = T_{OR} (20 + 1.46 $\log_{10}$ thr.) for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

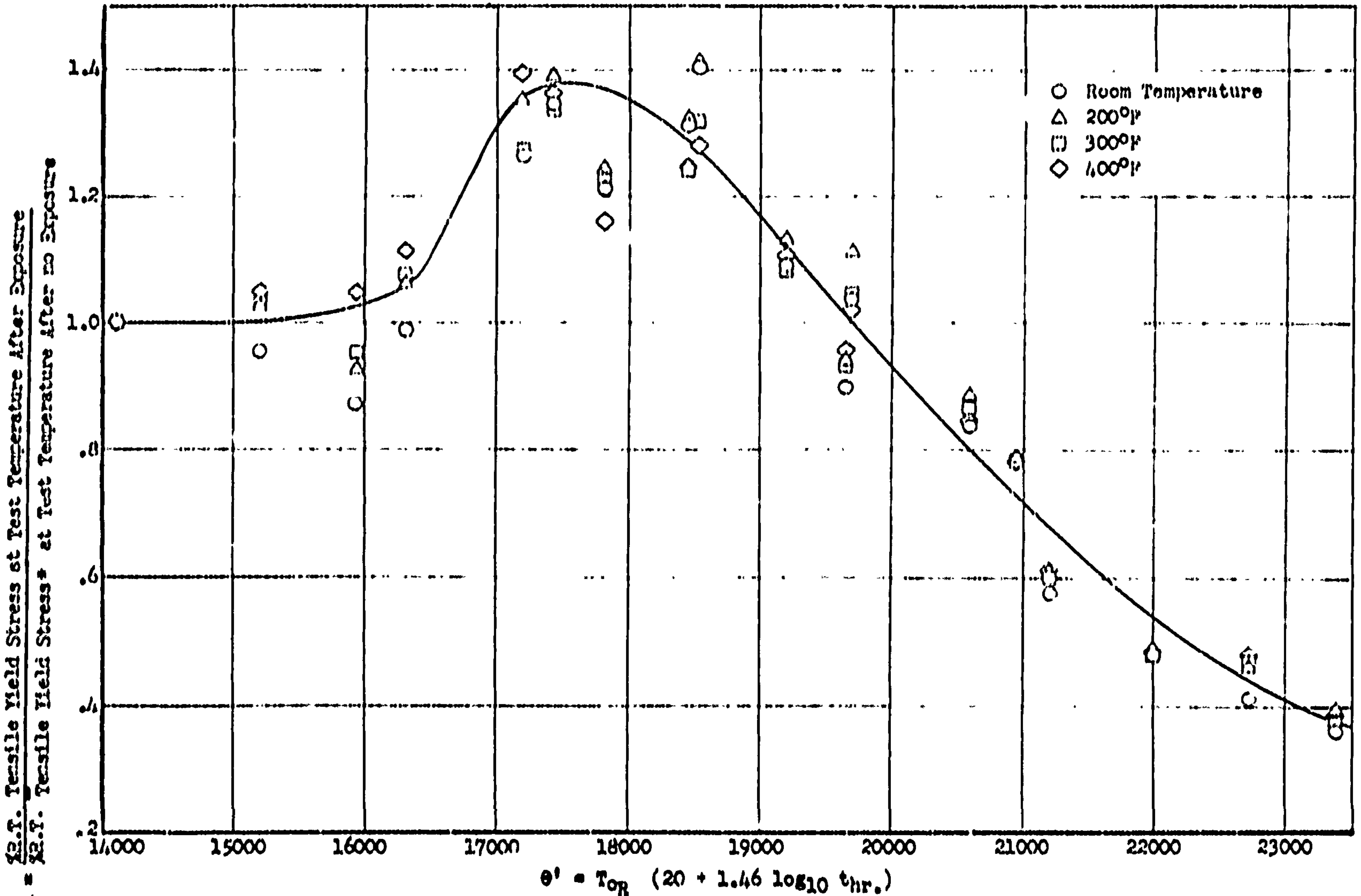


Figure 21. Ratio of Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After Exposure to Tensile Yield Stress* of 2024-T3 Clad Sheet at Test Temperature After no Exposure Versus Modified Time-Temperature Parameter, $\theta' = T_{^\circ R}\ (20 + 1.46 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.
* Ftu at Test Temperature after 0.1 hr., 300°F exposure.

Normalization of the tensile yield stress data is indicated in Figure 23. Normalization in this case has been achieved as follows:

$$R = \frac{x}{y - (100-y)\left(\frac{22{,}940 - \theta''}{17{,}460}\right)}$$

where R = The decimal fraction of the no exposure tensile yield stress at any given temperature which remains when tested at this same temperature after exposure of magnitude θ''.

x = The percent of room temperature tensile yield stress at the test temperature after being exposed to elevated temperature.

y = The percent of room temperature tensile yield stress at the same test temperature as for x after no exposure.

θ'' = The modified Larson-Miller parameter $\theta'' = T_{oR}\,(20 - 1.3\ \mathrm{LOG}_{10}\ t_{hr.})$ calculated for the exposure condition which determined x.

Although greater generalization resulted from the normalization procedure, accuracy was lost to the degree that the range to include approximately 95% of the test points is ± 8% of the room temperature tensile yield stress. The assumption that 0.1 hour exposure at 300°F is the same as no exposure is valid with the exception of the tests made at 200°F. The table below tabulates the test data for 0.1 hour exposure at 300°F test data for the 2024-T3 tensile yield stress.

Test Temperatures	% of Room Temperature Tensile Yield Stress	
	0.1 hour at 300°F	No Exposure
R.T.	98.0	100
200°F	91.1	98.8
300°F	89.2	92.8
400°F	79.5	77.6

Analysis of the Sequential Tests

Structural components of aircraft are not exposed to simple time-temperature exposures such as analyzed in the previous section. Instead, parts of airplanes are exposed to various temperatures for varying lengths

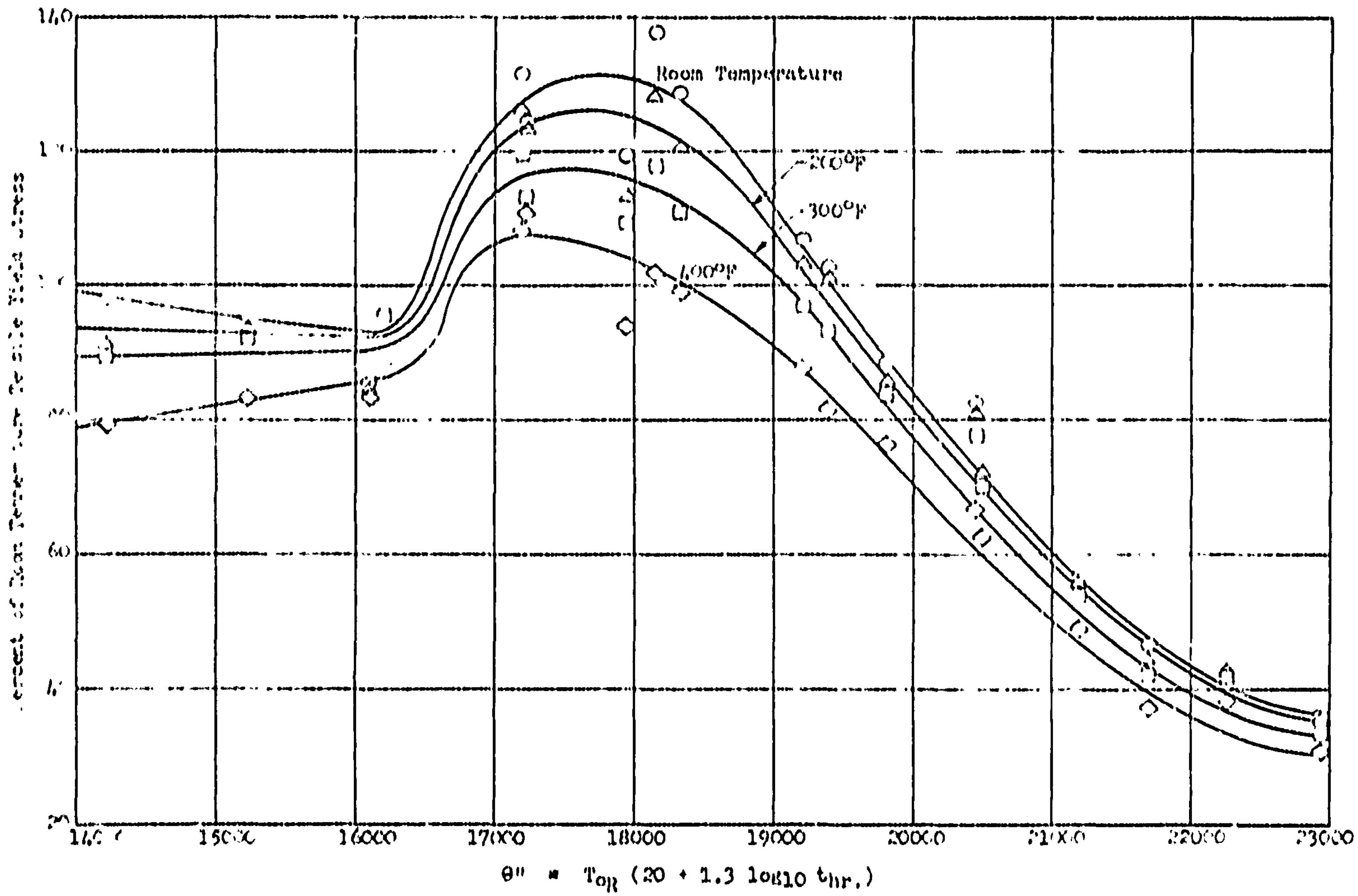


Figure 22. Percent of Room Temperature Tensile Yield Stress of 2024-T3 Alclad versus Modified Time - Temperature Parameter, $\theta'' = T_{°R}(20 + 1.3 \log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F, and 400°F Test Temperatures.

TABLE XII

STATISTICAL ANALYSIS OF TENSILE YIELD STRESS OF 2024-T3 ALCLAD VERSUS θ''

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
-12	2	-6	36	25	-12	72	50
-10	1	-5	25	16	-5	25	16
-[illegible]	2	-4	16	9	-8	32	18
-[illegible]	1	-3	9	4	-3	9	4
-[illegible]	3	-2	4	1	-6	12	3
-[illegible]	5	-1	1	0	-6	6	0
[illegible]	28	0	0	1	0	0	28
2	11	1	1	4	11	11	44
4	10	2	4	9	20	40	90
6	1	3	9	16	3	9	16
8	3	4	16	25	12	48	75
10	1	5	25	36	5	25	36
12	0	6	36	49	0	0	0
S	71				9		
SS						291	380
S^2/n						1	90
SSD						290	290
S_w^2					4.14		
S_w					2.03		
S/n					.125		

$\bar{x} = 2(.125) = .250$

$S_x = 2(2.0[illegible]) = [illegible]$

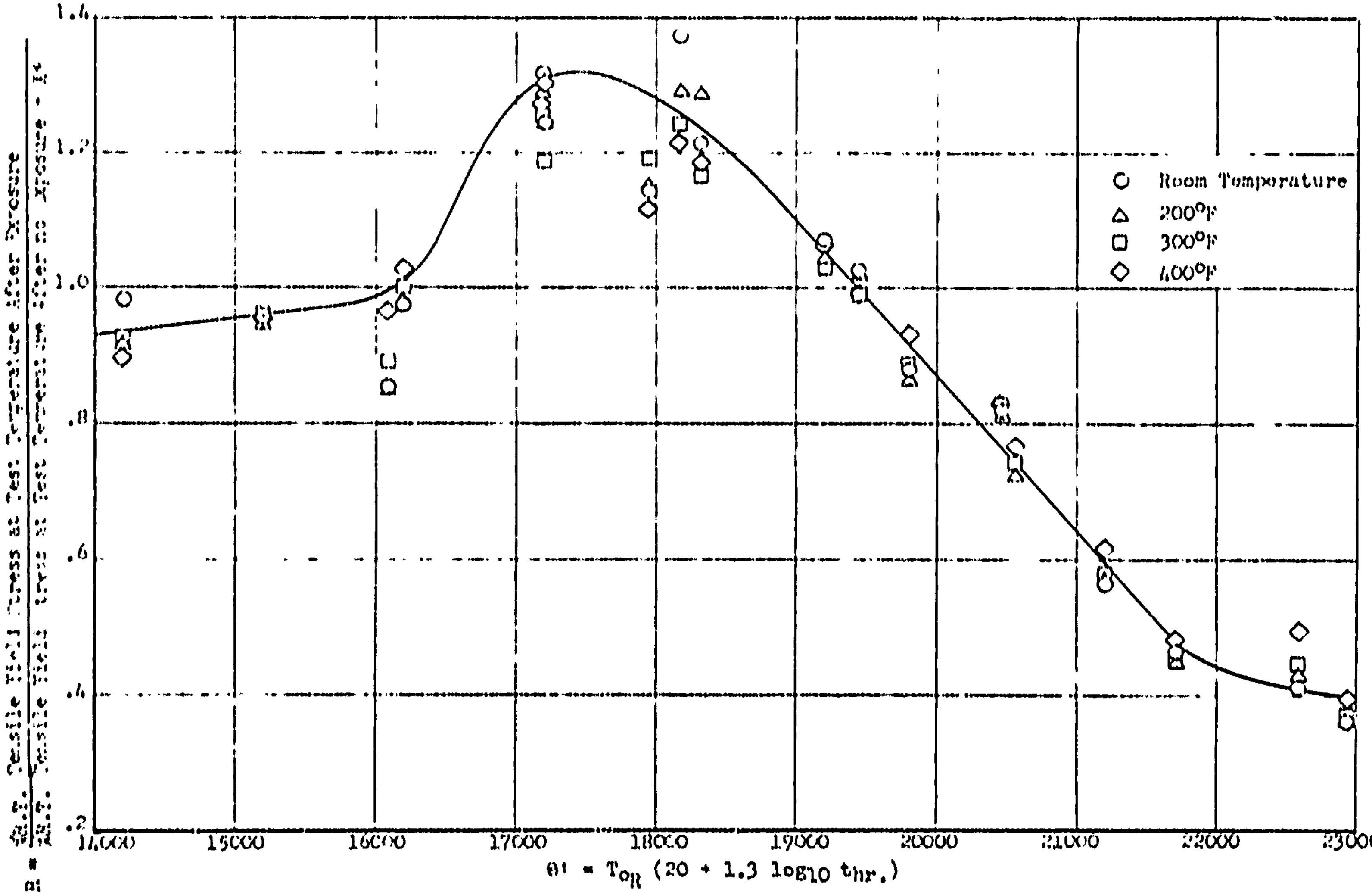


Figure 23. Ratio of Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After Exposure to Tensile Yield Stress of 2024-T3 Clad Sheet at Test Temperature After no Exposure + X* Versus Modified Time-Temperature Parameter, $\theta' = T_{oR}\,(20 + 1.3\,\log_{10} t_{hr.})$ for Room Temperature, 200°F, 300°F and 400°F Test Temperatures.

$*\ X = (100 - \%\ \text{R.T.}\ F_{ty}\ \text{at}\ {}^{\circ}\text{F, no exposure})\ \left(\dfrac{22{,}940 - \theta'}{17{,}460}\right)$

TABLE XIII

STATISTICAL ANALYSIS OF NORMALIZED TENSILE YIELD STRESS OF 2024-T3 ALCLAD VERSUS θ''

Class Midpoint	a	w	w^2	$(w+1)^2$	aw	aw^2	$a(w+1)^2$
12	1	6	36	49	6	36	49
10	0	5	25	36	0	0	0
8	1	4	16	25	4	16	25
6	4	3	9	16	12	36	64
4	4	2	4	9	8	16	36
2	6	1	1	4	6	6	24
0	15	0	0	1	0	0	15
-2	16	-1	1	0	-16	16	0
-4	10	-2	4	1	-20	40	10
-6	5	-3	9	4	-15	45	20
-8	0	-4	16	9	0	0	0
-10	0	-5	25	16	0	0	0
-12	1	-6	36	25	-6	36	25
S	63				-21		
SS						247	268
S^2/n						7	28
SSD						240	240
S_w^2						3.87	
S_w						1.97	
S/n					-.333		

$\bar{t} = 2(-.333) = -.667$

$S_t = 2(1.97) = 3.94$

of times. The sum of the individual times at each temperature is then looked upon as the exposure experience of the metal. It is desirable to evaluate what such a time temperature spectrum will do to the strength properties of the material, and to do so in terms of the simple exposure test data.

It is a simple calculation to determine the equivalent θ'_t or θ''_t for any sequence of exposures. The procedure for calculation of θt, for example, of any sequence of exposures at temperatures T_1, T_2, ...T_n for times t_1, t_2, ... t_n respectively, is summarized as follows:

1. Choose a reference temperature T_r

2. Calculate θ'_1, θ'_2, ... θ'_n

3. Determine t_{r1}, t_{r2}, ... t_{r_n}, the times at T_r which would give θ'_1, θ'_2, ... θ'_n respectively.

$$t_{r_i} = \text{antilog}_{10} \frac{\frac{\theta'_i - 20}{T_r}}{1.46}$$

4. Add t_{r_1}, t_{r_2}, ... t_{r_n} to obtain t_r, the total effective times at T_r which gives the equivalent θ'_t for the given sequence of exposures.

5. Calculate $\theta'_t = T_{r_{oR}} (20 + 1.46 \text{ LOG}_{10} t_{r_{hr.}})$. θ'_t is independent of the value chosen for T_r.

The above procedure will be evaluated by comparison with the sequential exposure test data.

a) Analysis of the Ultimate Tensile Stress of 7075-T6 Alclad Sheet

The values of the modified Larson-Miller parameter θ'_t for the nine sequential exposures are indicated with their respective time temperature spectrum in Table XIV. The first five spectra, although providing good agreement between calculated values for the percent of room temperature ultimate tensile stress and those obtained by tests, must not be considered as indicative of the accuracy of the analysis.

The reason for qualifying these results is due to the fact that the highest temperature of each sequence dominates the respective t_r.

TABLE XIV

SEQUENTIAL EXPOSURE OF 7075-T6 ALCLAD

θ'	Sequential Exposure Time and Temperature: First	Second	Third	Fourth	Test. Temp. °F	% R.T. F_{ty} After Expos.: Indiv.	Normalized R	Normalized %	Test	% R.T. F_{tu} After Expos.: Indiv.	Normalized R	Normalized %	Test
	1 hr.	10 hr.											
	400°F	300°F			R.T.	83.7	.883	88.0	79.8	84.8	.845	84.1	84.1
17,250	400	300			200	76.1	.883	82.4	76.5	73.4	.845	76.8	73.0
	400	300			300	69.0	.883	72.4	66.2	60.8	.845	61.0	58.6
	400	300			400	53.2	.883	58.3	52.6	48.4	.845	46.5	46.0
	1 hr.	10 hr.	100 hr.										
	400°F	300°F	250°F		R.T.	83.4	.835	83.2	79.4	84.4	.835	83.2	83.0
17,300	400	300	250		200	75.7	.835	77.9	76.9	72.9	.835	74.8	72.7
	400	300	250		300	68.7	.835	68.8	66.5	60.1	.835	60.2	58.8
	400	300	250		400	53.1	.835	56.3	53.1	47.6	.835	46.0	46.7
	1 hr.	10 hr.											
	500°F	400°F			R.T.	37.7	.394	39.3	37.5	54.0	.530	52.8	54.1
19,360	500	400			200	36.2	.394	37.2	37.0	48.7	.530	47.5	46.9
	500	400			300	34.1	.394	33.4	34.7	34.8	.530	38.2	33.9
	500	400			400	29.0	.394	27.9	29.3	25.9	.530	29.1	25.4
	1 hr.	10 hr.	100 hr.										
	500°F	400°F	300°F		R.T.	37.6	.392	39.1	38.7	53.7	.524	52.3	53.7
19,380	500	400	300		200	36.0	.392	37.0	37.7	48.4	.524	47.1	45.7
	500	400	300		300	34.0	.392	33.3	35.0	34.7	.524	37.8	33.1
	500	400	300		400	28.9	.392	27.8	29.1	25.8	.524	28.8	25.3
	1 hr.	10 hr.	100 hr.	1000 hr.									
	500°F	400°F	300°F	250°F	R.T.	37.4	.389	38.8	38.4	53.5	.521	51.9	53.4
19,400	500	400	300	250	200	35.8	.389	36.7	36.9	48.2	.521	46.7	45.0
	500	400	300	250	300	33.8	.389	33.0	34.1	34.5	.521	37.5	32.5
	500	400	300	250	400	28.8	.389	27.5	29.0	25.6	.521	28.6	25.2
	1 hr.	4.8 hr.	27.6 hr.	191.7 hr.									
	380°F	340°F	300°F	260°F	R.T.	79.8	.792	78.9	80.7	80.9	.794	79.2	82.5
17,540	380	340	300	260	200	71.7	.792	74.0	79.2	68.8	.794	71.2	72.1
	380	340	300	260	300	65.5	.792	65.6	72.9	55.1	.794	57.2	62.4
	380	340	300	260	400	50.6	.792	52.8	58.4	42.2	.794	43.7	50.4
	1 hr.	4.5 hr.	23.4 hr.	145.1 hr.									
	420°F	380°F	340°F	300°F	R.T.	57.3	.599	59.8	56.2	65.5	.656	65.4	65.6
18,370	420	380	340	300	200	54.1	.599	56.2	53.7	55.9	.656	58.8	55.3
	420	380	340	300	300	48.3	.599	50.1	49.5	42.8	.656	47.2	43.2
	420	380	340	300	400	39.8	.599	41.1	38.3	34.8	.656	36.1	33.8
	1 hr.	4.2 hr.	20.2 hr.	113.4 hr.									
	460°F	420°F	380°F	300°F	R.T.	39.8	.412	41.1	41.8	55.0	.547	54.5	56.2
19,210	460	420	380	300	200	38.4	.412	38.8	41.1	49.5	.547	49.1	47.9
	460	420	380	300	300	35.9	.412	34.8	38.5	36.0	.547	39.4	34.7
	460	420	380	300	400	30.4	.412	29.0	32.8	27.0	.547	30.1	28.0
	1 hr.	4.0 hr.	17.5 hr.	90.5 hr.									
	500°F	460°F	420°F	380°F	R.T.	31.2	.336	33.5	30.8	50.1	.462	46.1	48.2
20,040	500	460	420	380	200	30.0	.336	31.8	29.6	45.0	.462	41.4	43.4
	500	460	420	380	300	28.7	.336	28.8	29.2	30.6	.462	33.3	30.3
	500	460	420	380	400	24.6	.336	24.3	25.3	21.8	.462	25.4	22.2

Put more bluntly, the first five sequences differ but slightly from a single exposure environment. It is not surprising, therefore, that the percent of room temperature ultimate tensile stress of 7075-T6 calculated utilizing the individual curves of Figure 13 and the normalized curve of Figure 14 correlate with the test results to a degree comparable to the single exposure tests points themselves.

The last four sequential exposures are such that each temperature of the spectra provides equal contribution to t_e and are as true sequential exposures as are possible when consisting of only four individual exposures. Also, these last four sequential exposures are in the range of θ', where E is changing the most rapidly. This increases the meanfulness of the agreement between the calculated values of percent room temperature ultimate tensile stress and the test results. The agreement achieved utilizing the individual curves of Figure 13 may be appraised by the average error which is only 2% of the room temperature ultimate tensile stress. The largest error is 8.2%. When the normalized curve of Figure 14 is used, an average error of slightly less than 3% of the room temperature ultimate tensile stress is obtained. And the greatest error obtained is 6.7%. These data are tabulated in Table XVI.

b) Analysis of the Tensile Yield Stress of 7075-T6 Alclad Sheet

The values of the modified Larson-Miller parameter θ_Y' for the nine sequential exposures are listed with their corresponding time temperature spectrum in Table XIV. As was pointed out in (a) above, the first five exposures provide very good agreement between calculated values and tests results. But these results are not to be considered as any more than further substantiation of the accuracy of the curves in predicting the single exposure behavior of 7075-T6. It is worth reiterating that the last four sequential exposures are as severe in checking the validity of the method of calculation as any four-step sequential exposure can be. The substantiation obtained from these four sequential exposures is, therefore, considered extremely indicative of the correctness of the procedure utilized. The average error between the values calculated from the individual curves and the test values of the last four sequences of Table XIV is 2.6% of the room temperature tensile stress. When the normalized curve is used to obtain the calculated values, this average error is 2.9%.

c) Analysis of the Ultimate Tensile Stress of 2024-T3 Alclad Sheet

The nine sequential exposure values, θ'', for 2024-T3 alclad sheet are tabulated in Table XV with their respective time temperature spectrum. Again, as with the 7075-T6 sequential tests, the first five sequences are of no value in evaluating the method for calculating the mechanical properties after a sequence of exposures.

TABLE XV

SEQUENTIAL EXPOSURE OF 2024-T3 ALCLAD

θ'	Sequential Exposure Time and Temperature First	Second	Third	Fourth	Test. Temp. °F	% R.T. F_{ty} After Expos. Indiv.	Normalized R	Normalized %	Test	% R.T. F_{tu} After Expos. Indiv.	Normalized R	Normalized %	Test
	1 hr.	10 hr.											
	500°F	400°F			R.T.	103.4	1.031	103.1	105.5	88.0	.862	86.2	87.5
19,300	500	400			200	100.0	1.031	102.1	103.2	81.8	.862	81.1	80.5
	500	400			300	95.6	1.031	97.3	95.4	70.2	.862	69.6	68.8
	500	400			400	85.9	1.031	84.9	83.7	57.6	.862	60.3	57.7
	1 hr.	10 hr.	100 hr.										
	500°F	400°F	300°F		R.T.	103.2	1.029	103.2	106.7	87.9	.861	86.1	87.8
19,310	500	400	300		200	99.8	1.029	101.8	103.8	81.7	.861	81.0	80.4
	500	400	300		300	95.4	1.029	97.0	93.1	70.1	.861	69.5	68.2
	500	400	300		400	85.7	1.029	84.8	81.3	57.5	.861	60.2	56.7
	1 hr.	10 hr.											
	600°F	500°F			R.T.	53.6	.561	56.1	60.0	63.2	.669	66.9	66.3
21,350	600	500			200	52.2	.561	55.4	56.3	58.3	.669	62.2	61.8
	600	500			300	48.6	.561	52.4	53.5	52.3	.669	51.6	50.8
	600	500			400	44.4	.561	44.6	48.8	38.0	.669	43.0	38.4
	1 hr.	10 hr.	100 hr.										
	600°F	500°F	400°F		R.T.	53.0	.554	55.4	56.4	62.9	.663	66.3	62.3
21,370	600	500	400		200	51.6	.554	54.8	51.2	58.2	.663	61.6	54.9
	600	500	400		300	48.2	.554	51.7	49.4	52.2	.663	51.1	46.4
	600	500	400		400	44.2	.554	44.1	46.4	37.9	.663	42.6	37.5
	1 hr.	10 hr.	100 hr.	1000 hr.									
	600°F	500°F	400°F	300°F	R.T.	52.8	.552	55.2	60.6	62.8	.662	66.2	65.1
21,380	600	500	400	300	200	51.4	.552	54.1	56.4	58.1	.662	61.5	57.0
	600	500	400	300	300	48.0	.552	51.6	54.3	52.1	.662	51.0	49.4
	600	500	400	300	400	44.0	.552	43.9	49.7	37.8	.662	42.4	39.7
	1 hr.	5 hr.	30 hr.	219 hr.									
	465°F	420°F	375°F	330°F	R.T.	115.3	1.130	113.0	127.2	92.4	.902	90.2	99.0
18,880	465	420	375	330	200	111.1	1.130	111.9	118.8	86.0	.902	80.7	88.9
	465	420	375	330	300	104.2	1.130	106.8	108.9	73.9	.902	73.5	76.5
	465	420	375	330	400	92.8	1.130	93.9	95.9	61.8	.902	64.0	64.2
	1 hr.	4.6 hr.	25.2 hr.	164.0 hr.									
	510°F	465°F	420°F	375°F	R.T.	89.0	.916	91.6	101.6	82.3	.807	80.7	86.6
19,810	510	465	420	375	200	86.2	.916	90.6	92.0	75.7	.807	75.8	75.6
	510	465	420	375	300	81.8	.916	86.2	83.8	65.5	.807	64.4	63.1
	510	465	420	375	400	74.5	.916	74.7	74.6	52.2	.807	56.3	52.1
	1 hr.	4.3 hr.	21.5 hr.	126.1 hr.									
	555°F	510°F	465°F	420°F	R.T.	66.1	.699	69.9	68.2	70.2	.718	71.8	69.4
20,750	555	510	465	420	200	64.0	.699	69.2	65.3	64.6	.718	67.0	62.8
	555	510	465	420	300	60.0	.699	65.4	61.1	57.1	.718	56.2	52.0
	555	510	465	420	400	55.0	.699	56.2	55.6	42.3	.718	47.3	42.7
	1 hr.	6.0 hr.	16.6 hr.	99.6 hr.									
	600°F	555°F	510°F	465°F	R.T.	47.0	.469	46.9	51.7	59.3	.635	63.5	61.8
21,760	600	555	510	465	200	45.6	.469	46.4	43.3	55.0	.635	58.8	52.2
	600	555	510	465	300	42.3	.469	43.7	43.5	49.3	.635	48.5	44.4
	600	555	510	465	400	38.7	.469	37.1	39.2	35.7	.635	40.1	33.8

Visual appraisal of the results of the first five sequential tests and the calculated values indicates that the agreement is not as good as that of the comparable 7075-T6 values. But, it is judged that the agreement between the calculated values and the respective test results for the first five sequential exposures of Table XV are in close agreement with the single exposure results.

The last four sequential exposures appearing in Table XV provide a valid check of the method of calculation of the mechanical properties after exposure. These results show an average error of 2.6% when the calculated values are based on individual curves of Figure 18. When the normalized curve of Figure 19 is the basis for the calculated values then the average difference is 4.1%. The difference between these two mean deviations is comparable to the difference between the average errors for the single exposure.

d) Analysis of the Tensile Yield Stress of 2024-T3

As for the ultimate tensile stress of 2024-T3, the tensile yield stress data for the nine sequential exposures is given in Table XV. As previously, the first five sequences are only a further check of the single exposure analysis.

The last four sequential exposures given in Table XV provide the check of the method for calculating the tensile yield stress of 2024-T3 after the material has been exposed to a spectrum of time-temperature exposure. In this particular case, the normalized curve of Figure 23 provides a lower average error than do the individual curves of Figure 22 in predicting the tensile yield stress. The normalized curve gives an average error of 3.62% of the room temperature tensile yield stress and the individual curves give an average error of 3.85% of the room temperature strength.

e) Consideration of Sequential Exposures More Complex than Four Single Exposures

Although no sequential exposures more complex than four single exposures were tested, the results may be extended through the assumption that intermittent heating of 2024-T3 and 7075-T6 aluminum alloys is equivalent to continuous heating. This assumption has been made for a number of years, having been recommended by the ANC-5 Bulletin, "Strength of Metal Aircraft Elements", June 1951. Test data has been obtained by the Aluminum Company of America which shows that the properties of 2024-T4 rolled and drawn bar and similarly the properties of 7075-T6 extended bar do not differ appreciably whether heated continuously or in 20 hours increments under the following conditions:

1) At room temperature and 300°F after 100 hours exposure to 300°F.

2) At room temperature and 300°F after 200 hours exposure to 300°F.

3) At room temperature and 400°F after 100 hours exposure to 400°F.

4) At room temperature and 400°F after 200 hours exposure to 400°F.

These data are published in NACA TM 1419.

Single exposures, to four different temperatures, may be considered as ten single exposures to each of four temperatures or a total of 40 exposures. Therefore, the test results of the last four sequential tests tabulated in Tables 14 and 15, represent test results after 8 sequential exposures where each of the sequential exposures may be considered to consist of 40 exposures divided evenly among four separate temperatures. These test results are in good agreement with the calculated values. For the individual curves, the calculated values average 1.725 percent lower than the test results and for the normalized curves, the calculated values average .275 percent lower than the test results. Although the normalized curves provided the smaller difference between calculated values and test results, the range was -14.2% to +6.6% while the comparison between calculated values from individual curves and the test results ranged from -12% to +6.6%. All of the extreme differences came from the 2024-T3 test results. As the significant error is conservative, the individual curves and normalized curves can be used for more complex sequences than 40 exposures.

CONCLUSIONS

Conclusions based upon the analysis presented in Table XVI and in the previous section may be stated as follow:

1) The ultimate tensile stress and tensile yield stress of 7075-T6 and 2024-T3 Alclad sheet can be predicted at room temperature, 200°F, 300°F and 400°F after single exposure with a 95% confidence that the results are within 5.9% of the respective room temperature stress of the actual strength by using the individual curves presented in Figures 13, 15, 18, and 22.

2) The strength properties of 7075-T6 and 2024-T3 Alclad sheet can be predicted at any temperature from room temperature to 400°F after single exposure with a 95% confidence that the results are with 7.7% of the respective room temperature strength of the actual strength by utilizing the normalized curves presented in Figures 14, 16, 19, and 23.

3) The individual curves of Figures 13, 15, 18, and 22 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at room temperature, 200°F, 300°F, and 400°F after sequential exposures, as complex as four single exposures, to within 6.9% of the respective room temperature strength 95% of the time.

4) The normalized curves of Figure 14, 16, 19, and 23 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at any temperature from room temperature to 400°F after sequential exposures, as complex as four single exposures, to within 8.4% of the respective room temperature strength 95% of the time.

5) The individual curves of Figures 13, 15, 18, and 22 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at room temperature, 200°F, 300°F, and 400°F after sequential exposures as complex as 10 single exposures to each of four temperatures(40 exposures) or even more complex exposures with good agreement.

6) The normalized curves of Figures 14, 16, 19, and 23 can be used to predict the strength properties of 7075-T6 and 2024-T3 Alclad sheet at any temperature from room temperature to 400°F after sequential exposures as complex is 10 single exposures to each of four temperatures (40 exposures) or even more complex exposures with good agreement.

TABLE XVI

ANALYSIS OF SEQUENTIAL EXPOSURE OF
7075-T6 ALCLAD AND 2024-T3 ALCLAD

	7075-T6				2024-T3			
	Yield		Ultimate		Yield		Ultimate	
	Indiv.	Norm.	Indiv.	Norm.	Indiv.	Norm.	Indiv.	Norm.
	-0.9	-1.8	-1.6	-3.3	-11.9	-14.2	-6.6	-8.8
	-7.5	-5.2	-3.3	-0.9	-[illegible].7	-6.9	-2.9	-8.2
	-7.4	-7.3	-7.2	-5.2	-4.7	-2.1	-2.6	-3.0
	-7.8	-5.6	-8.2	-6.7	-3.1	-2.0	-2.4	-0.2
	1.1	3.6	-0.1	-0.2	-12.6	-10.0	-4.3	-5.9
	0.5	2.5	0.6	3.5	-5.8	-1.4	0.1	0.2
	-1.2	0.5	-0.4	4.0	-2.0	2.4	2.4	1.3
	1.5	2.8	1.0	2.3	-0.1	0.1	0.1	4.2
	-2.5	-0.7	-1.2	-1.7	-1.7	1.7	0.8	2.4
	-2.7	-2.3	1.6	1.2	-1.3	3.9	1.8	4.2
	-2.6	-3.7	2.1	4.7	-1.1	4.3	5.1	4.2
	-2.4	-3.8	-1.0	2.1	-0.6	0.6	-0.4	4.0
	0.4	2.7	1.9	-2.1	-4.7	-4.8	-2.5	1.7
	-0.5	-0.4	0.3	2.0	2.3	3.1	2.8	6.6
	-0.7	-1.0	-0.4	3.2	-1.2	0.2	4.9	4.1
					-0.5	-2.1	1.9	6.3
Absolute Sum.	39.2	43.9	31.0	43.1	61.7	59.8	41.6	65.9
Absolute Ave.	2.6	2.9	2.1	2.9	3.8	3.6	2.6	4.1
Algebraic Sum.	-32.2	-19.7	-16.0	2.1	-57.1	-27.2	-1.8	25.5
Albegraic Ave.	-2.1	-1.3	-1.1	0.2	-3.6	-1.7	-0.1	1.7
S_t	2.4	3.6	2.4	4.0	4.0	3.9	3.0	4.0
$\bar{t}$	0.7	-0.7	0.8	-0.9	0.2	-0.7	-0.04	-0.2

Absolute Ave.

	Indiv.	Norm.
	2.6	2.9
	2.1	2.9
	3.8	3.6
	2.6	4.1
Sum	11.1	13.5
Ave.	2.78	3.38
$\sqrt{\frac{\pi}{2}}$ Ave.	3.48	4.24

S_t

Indiv.	Norm.
2.4	3.6
2.4	4.0
4.0	3.9
3.0	4.0
11.8	15.5
2.95	3.88

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APPENDIX I

TABULATED AND GRAPHICAL DATA

Summarized tensile properties for each alloy and condition are presented in Tables XVII through XX.

Graphical presentation of the summarized tensile properties for each alloy and condition is presented in Figures 24 through 103.

Hardness test data are presented in Tables XXI and XXII and Figures 104 through 111 for both alloys.

Tensile test results for each specimen are presented in Table XXIII through XXXIV.

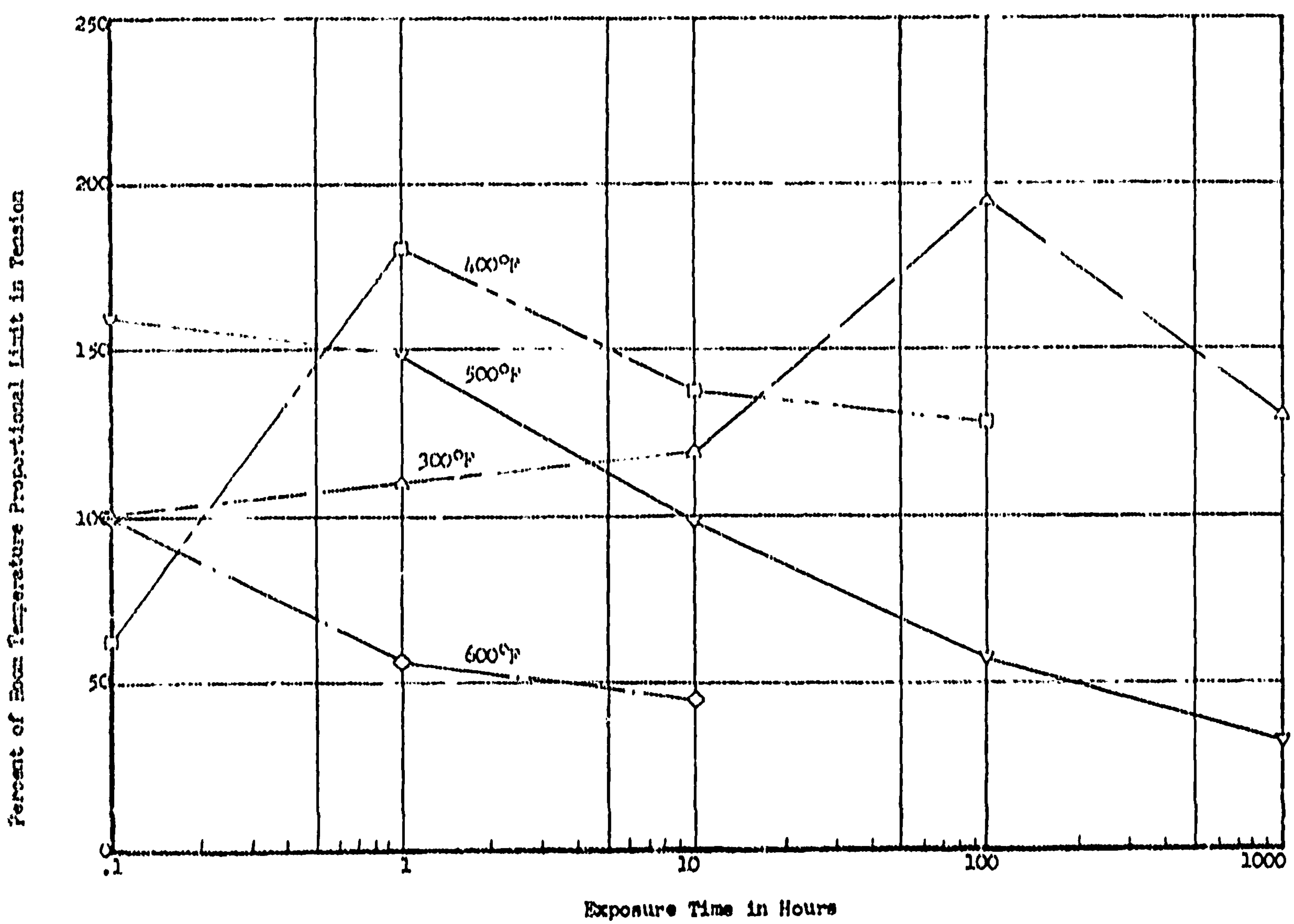

Figure 24. Proportional Limit in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

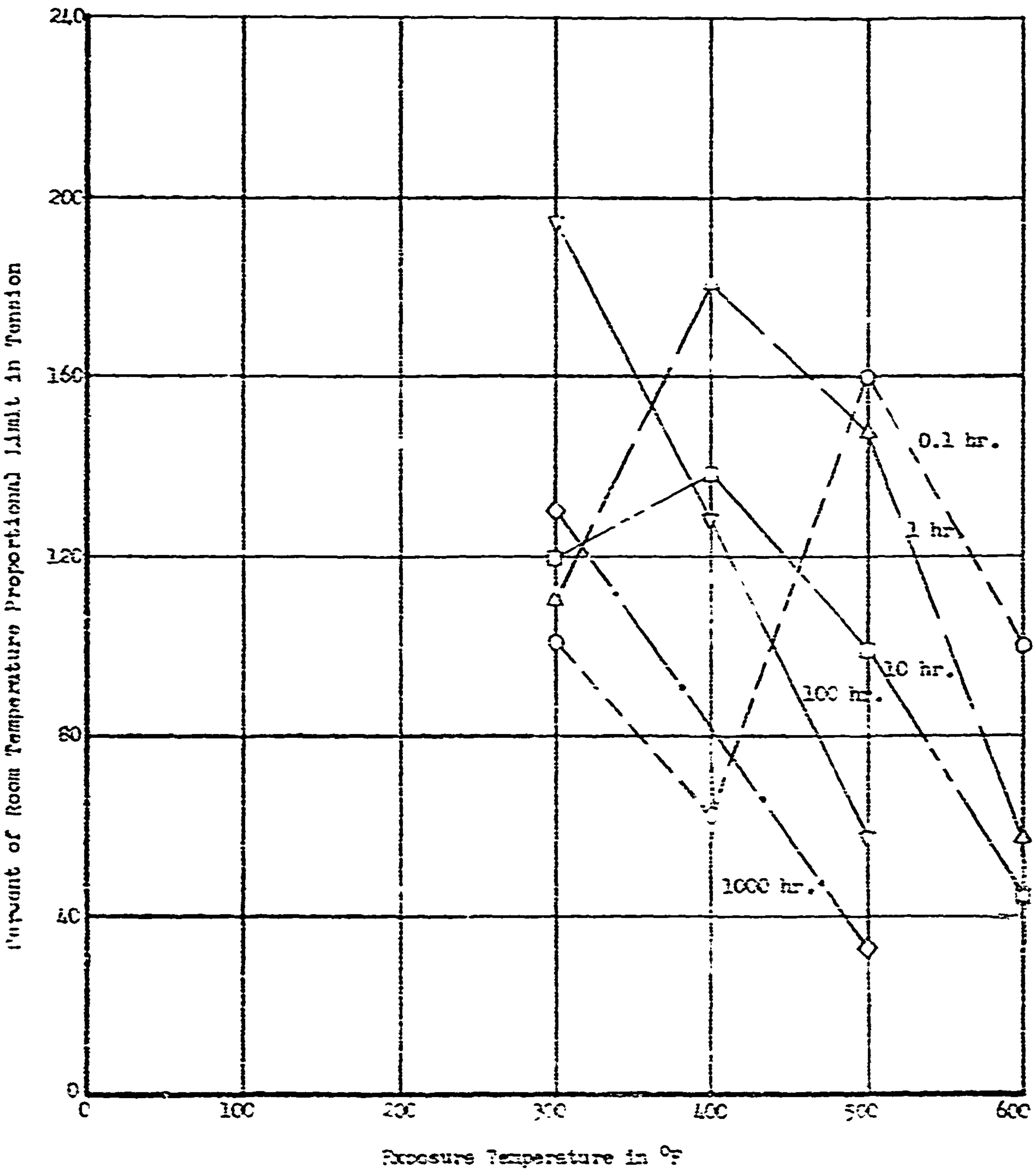

Figure 25. Proportional Limit in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

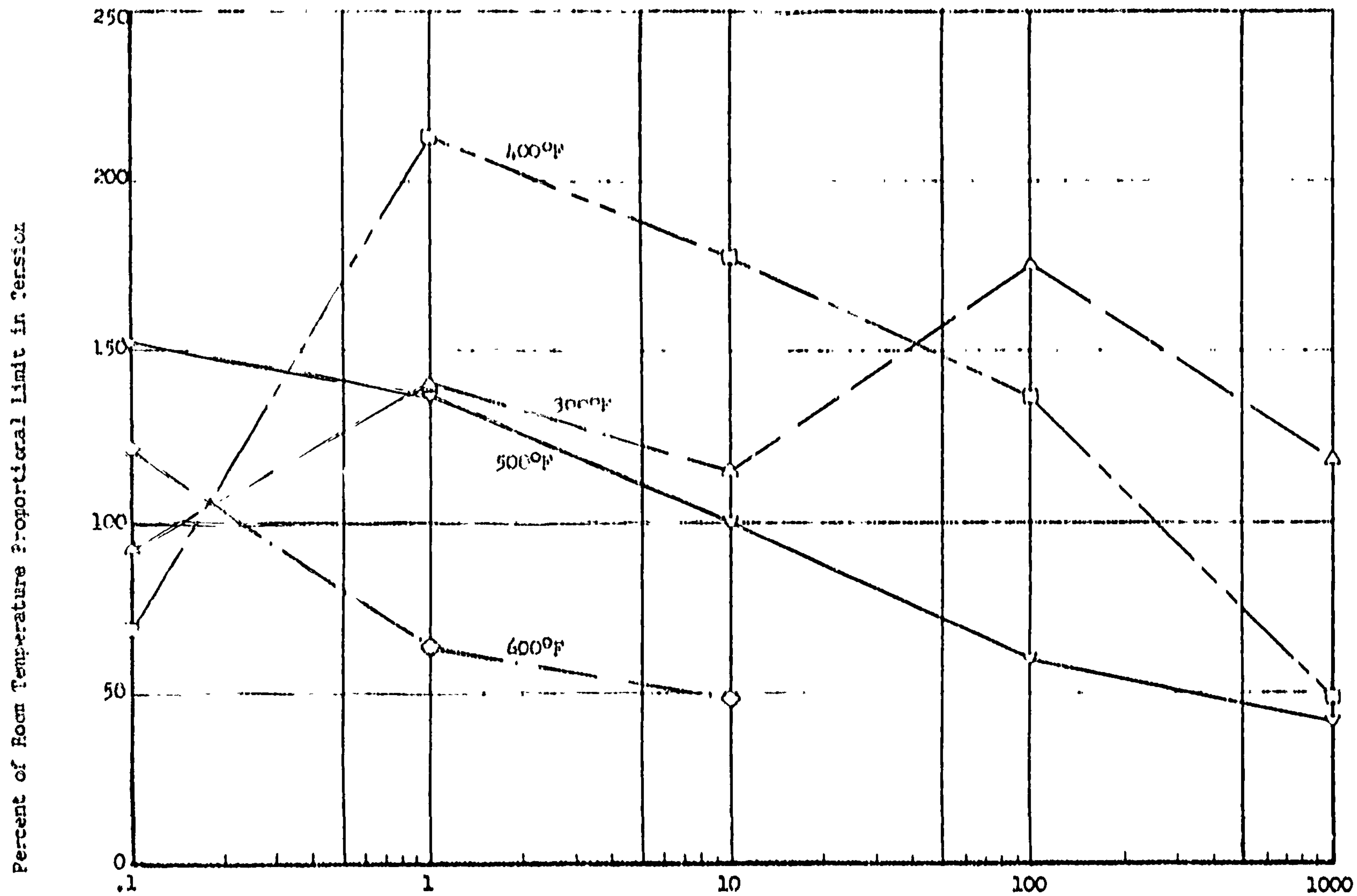

Figure 26. Proportional Limit in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

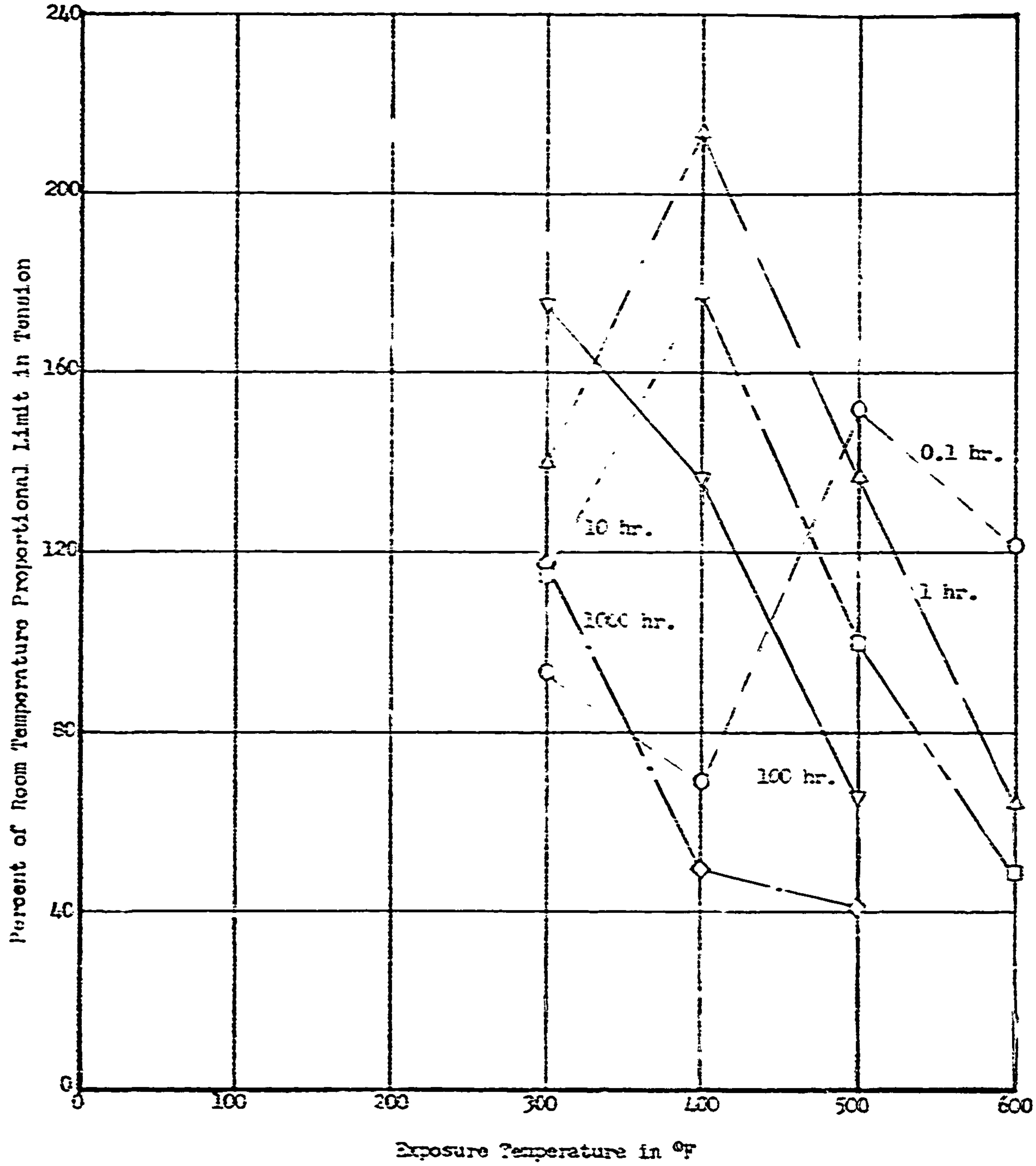

Figure 27. Proportional Limit in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

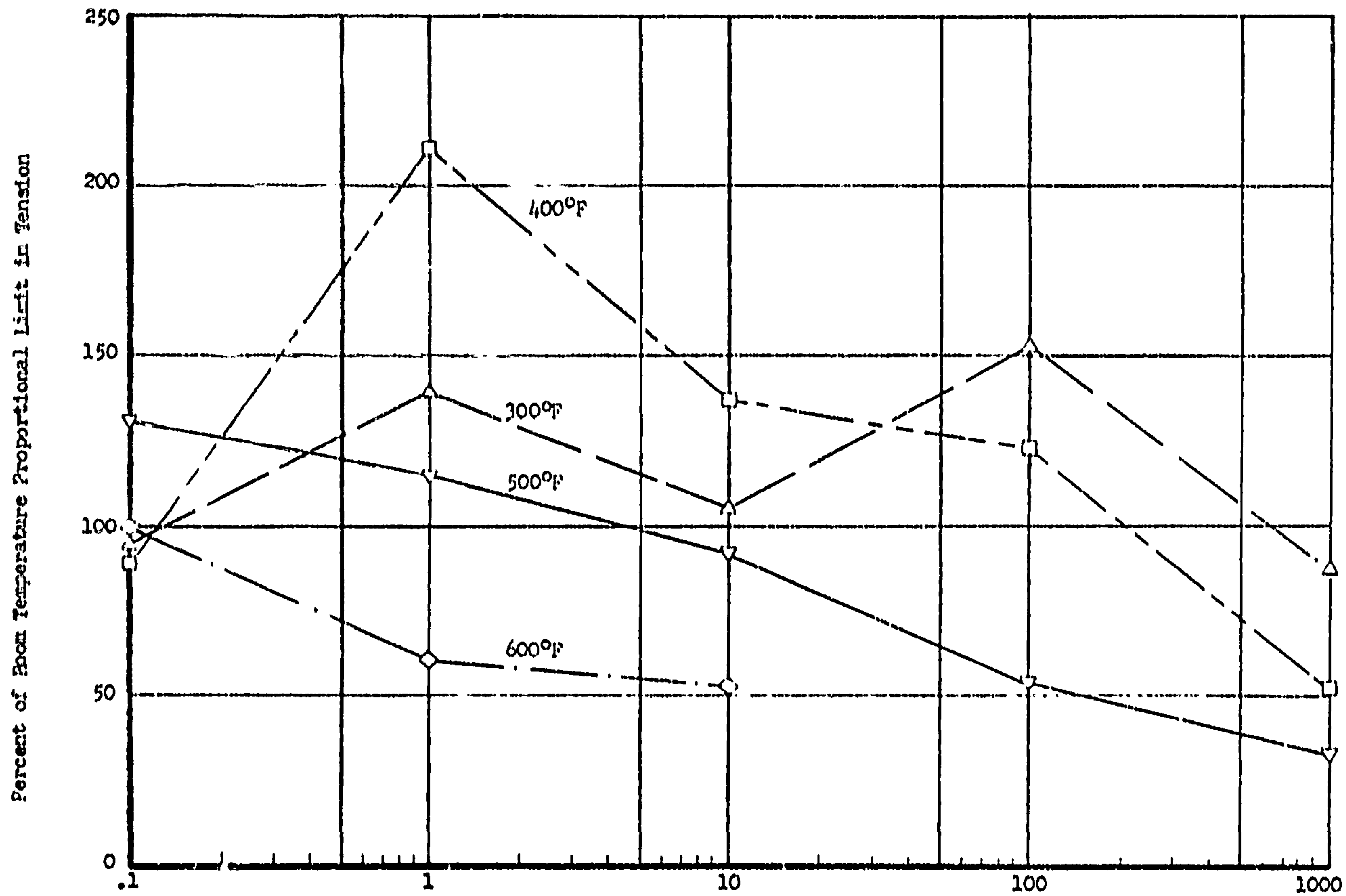

Figure 28. Proportional Limit in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

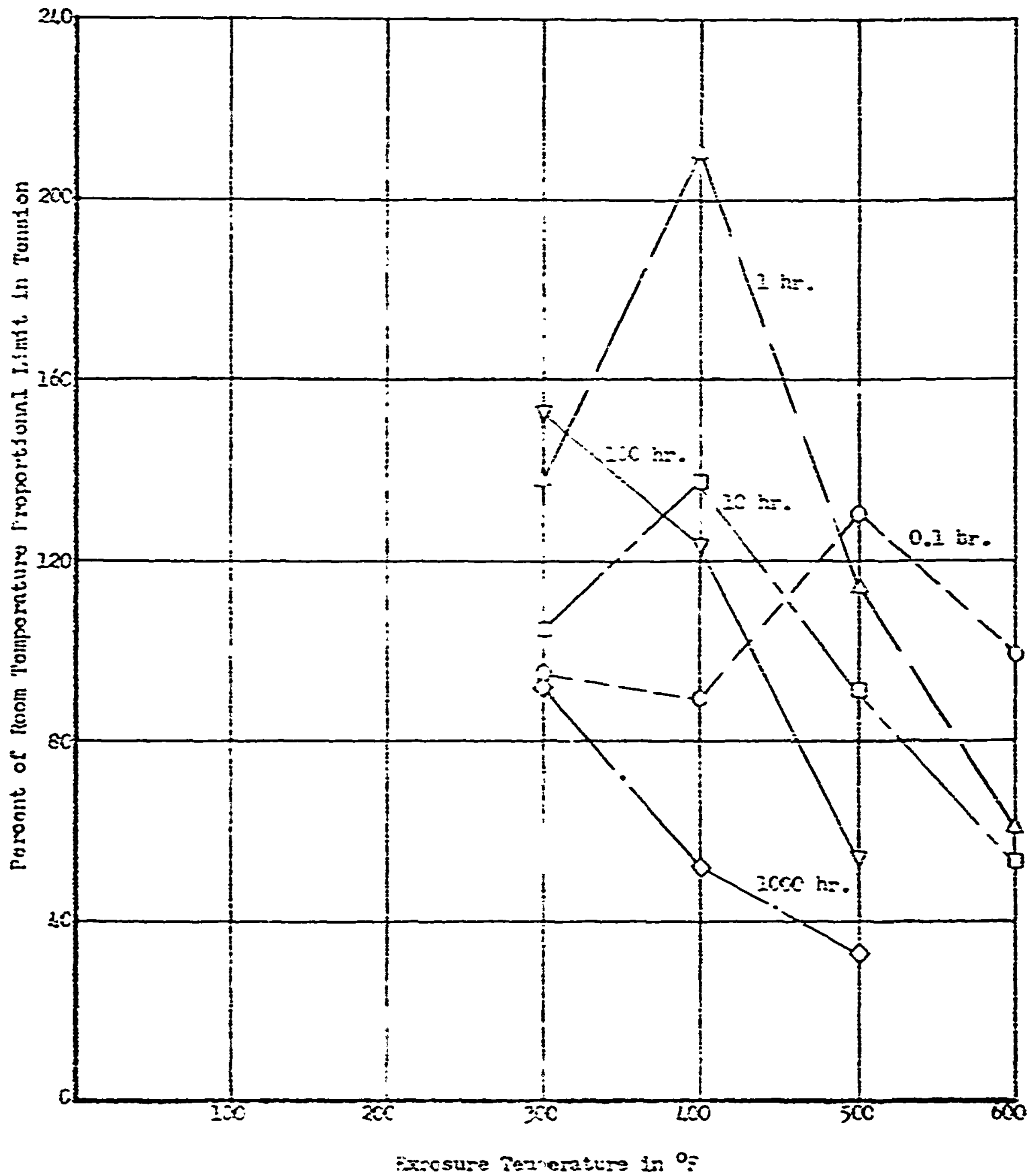

Figure 29. Proportional Limit in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

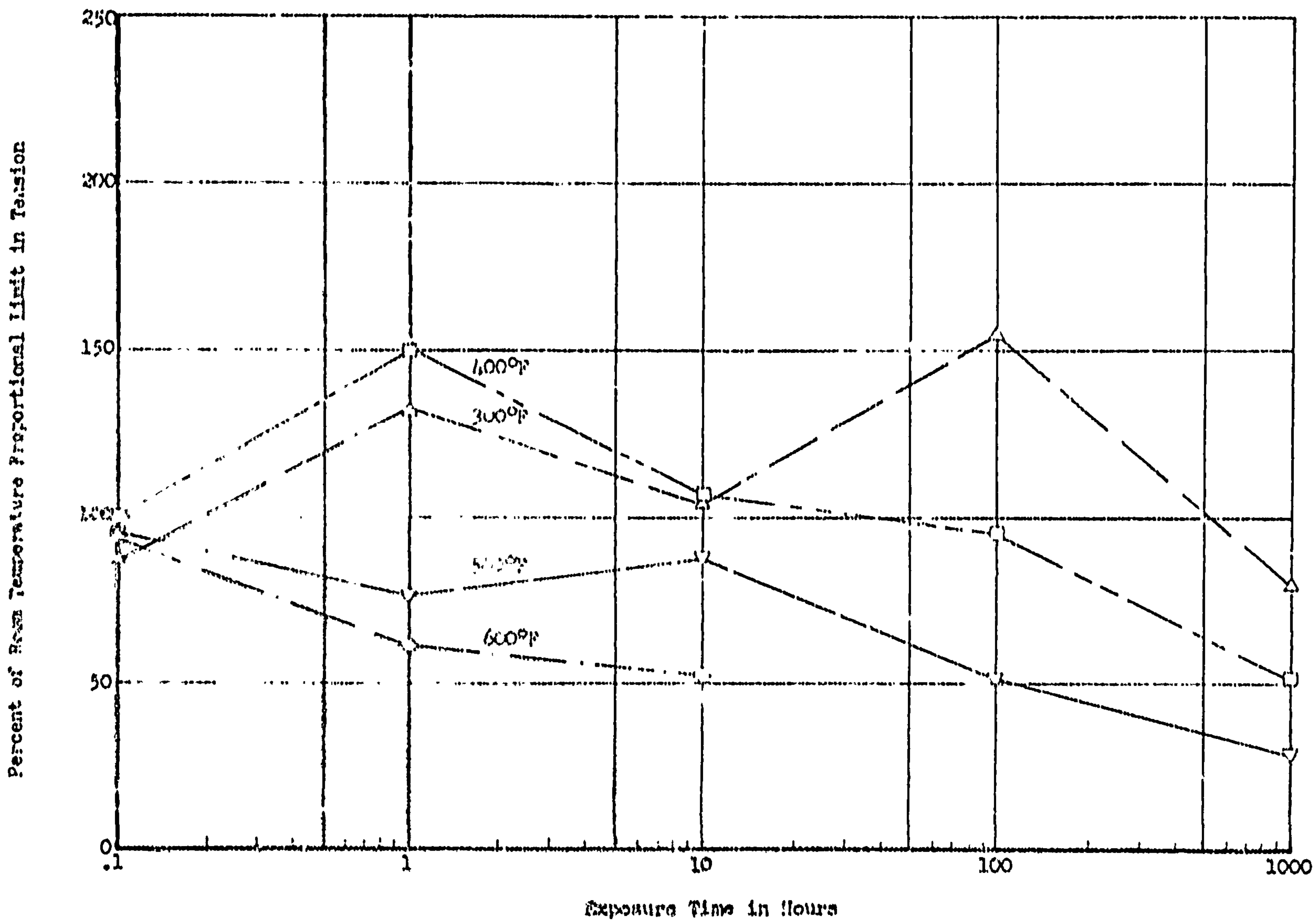

Figure 30. Proportional Limit in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

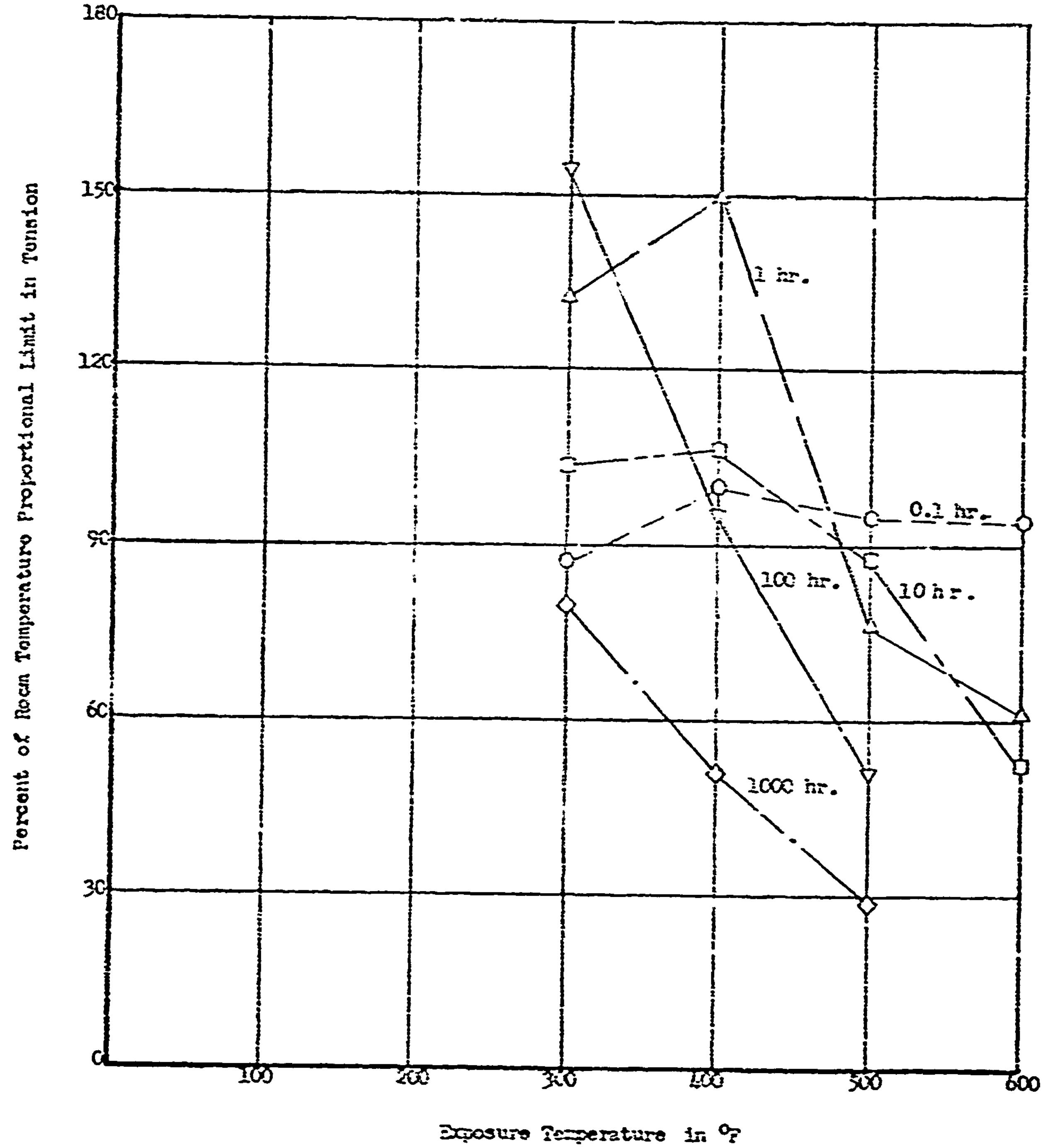

Figure 31. Proportional Limit in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

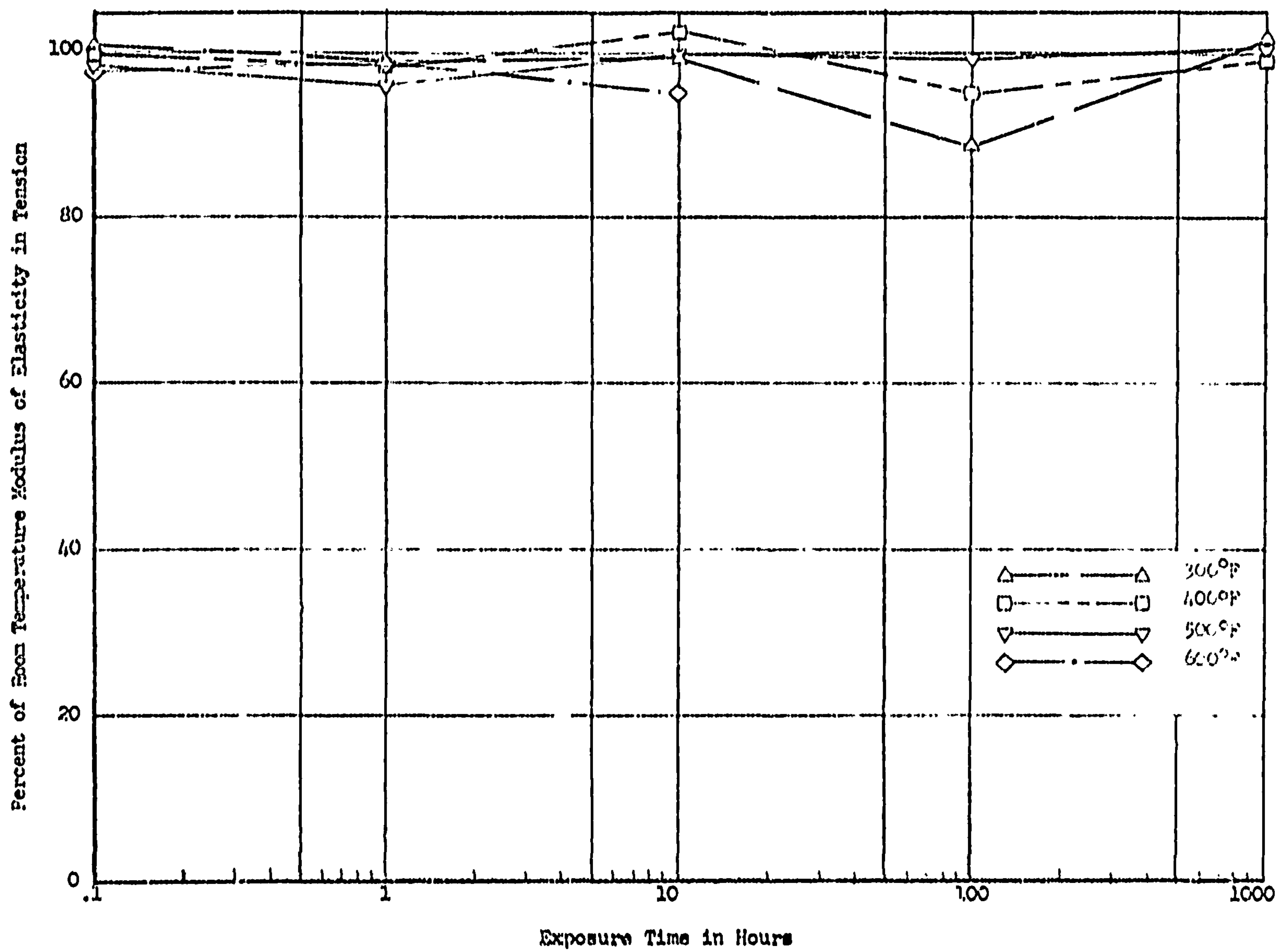

Figure 32. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

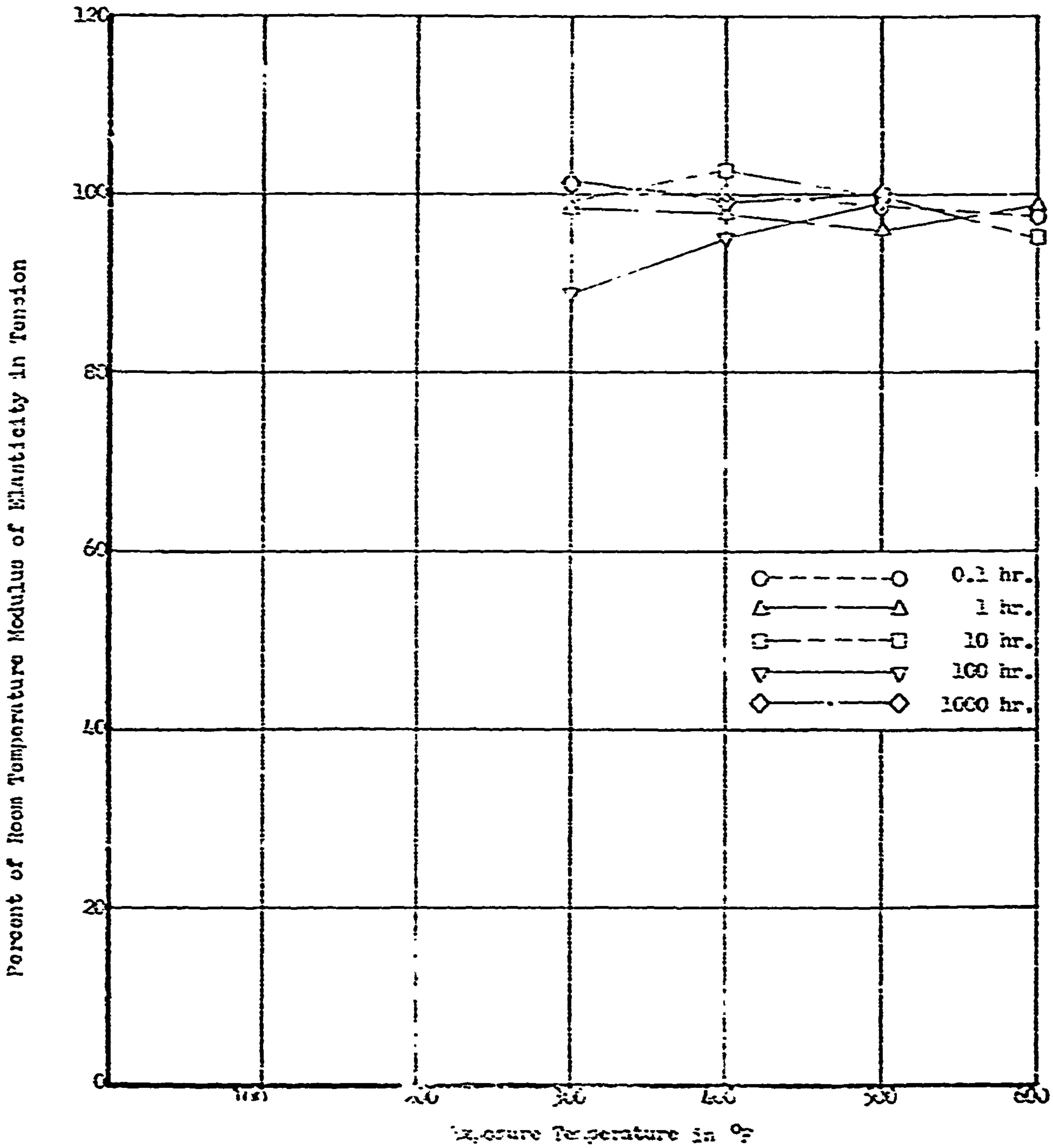

Figure 33. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

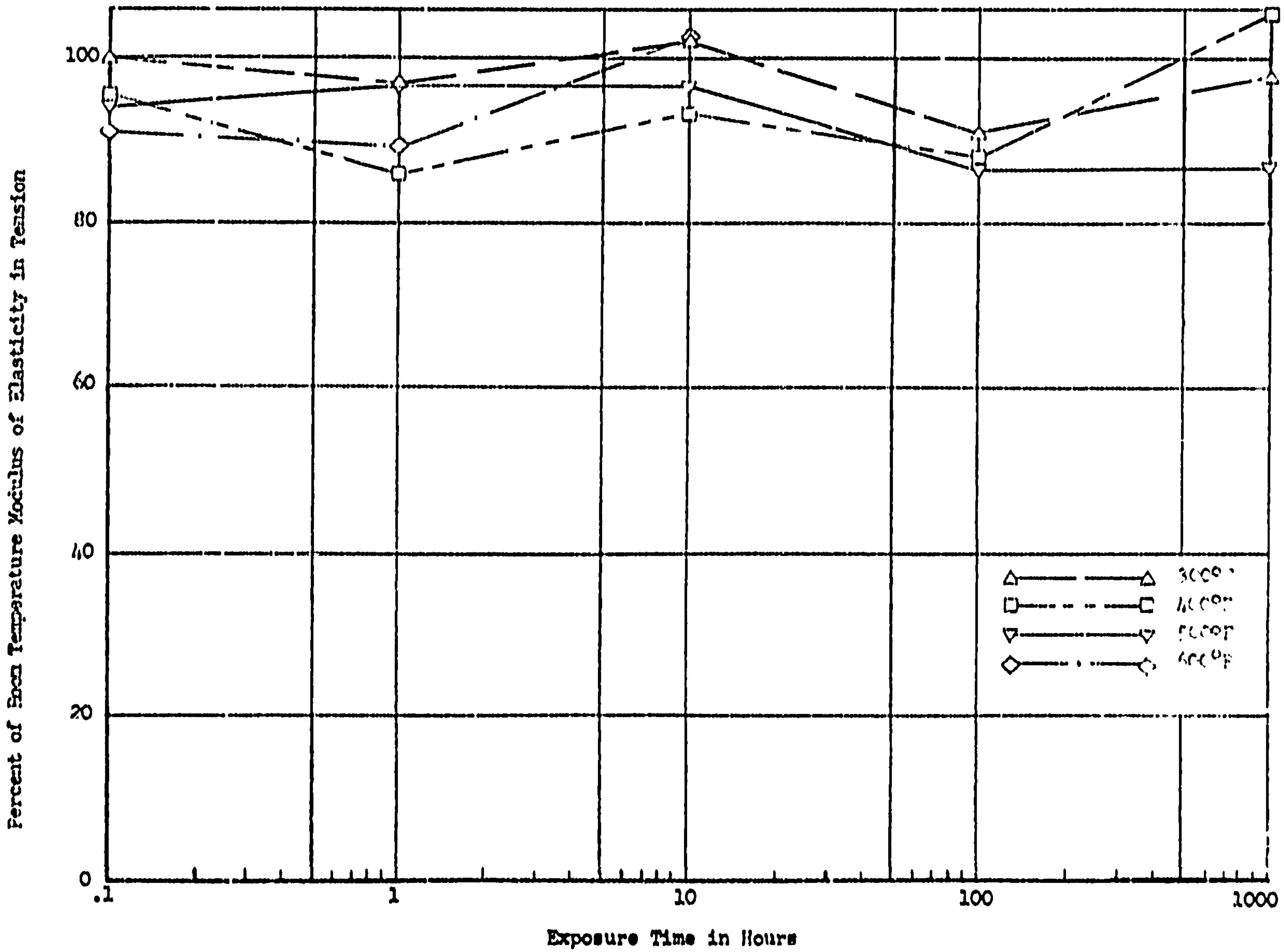

Figure 34. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

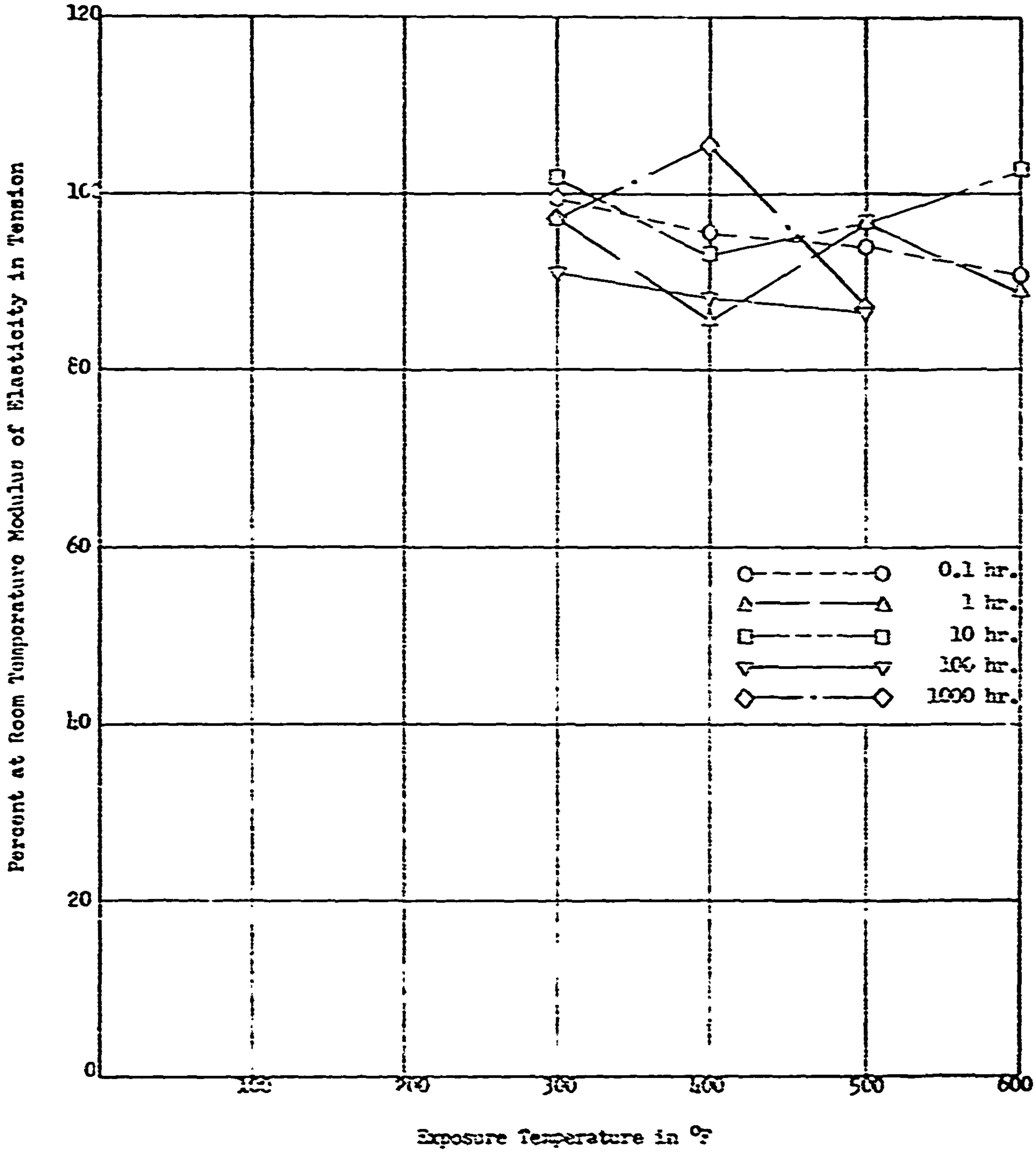

Figure 35. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

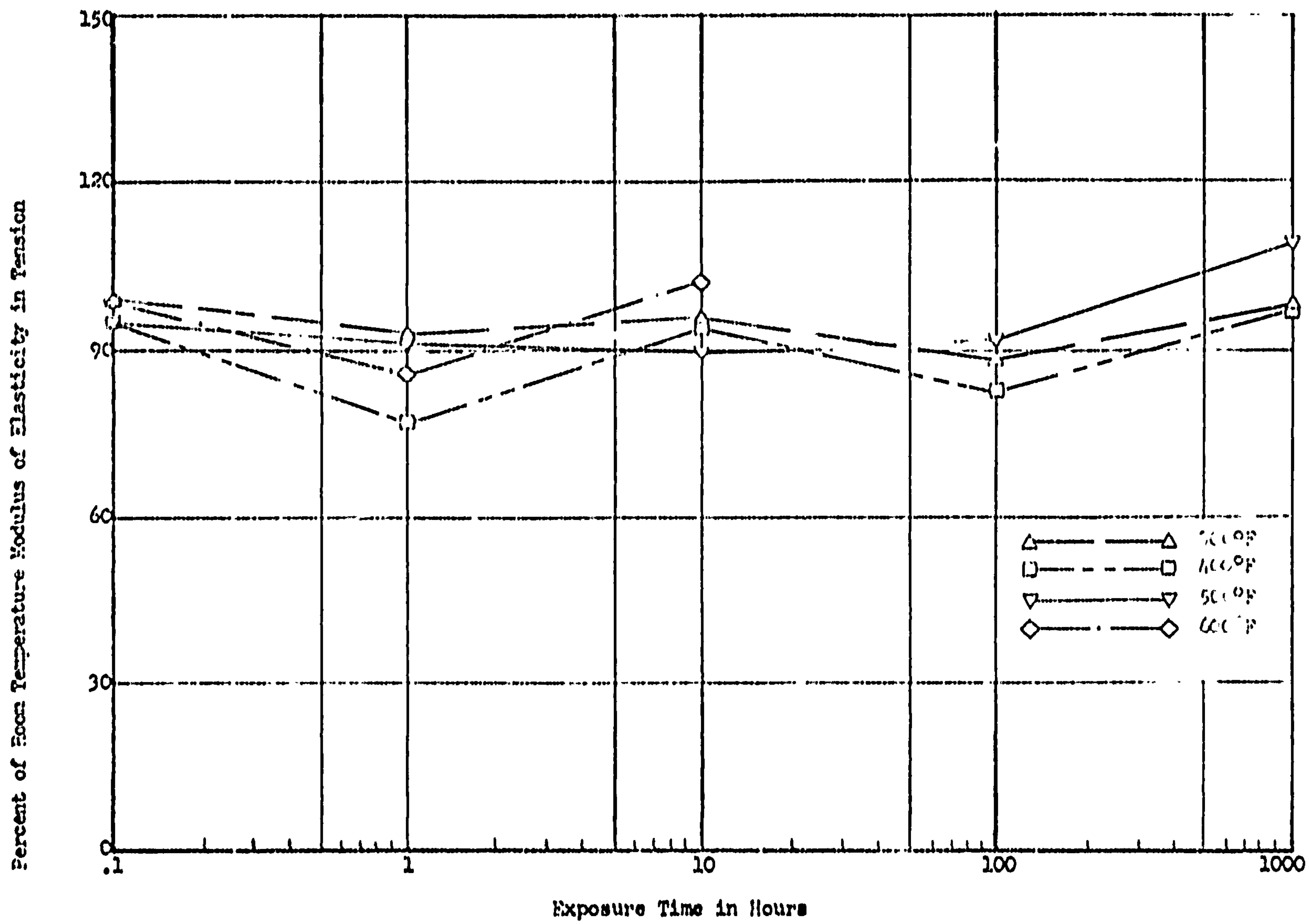

Figure 36. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

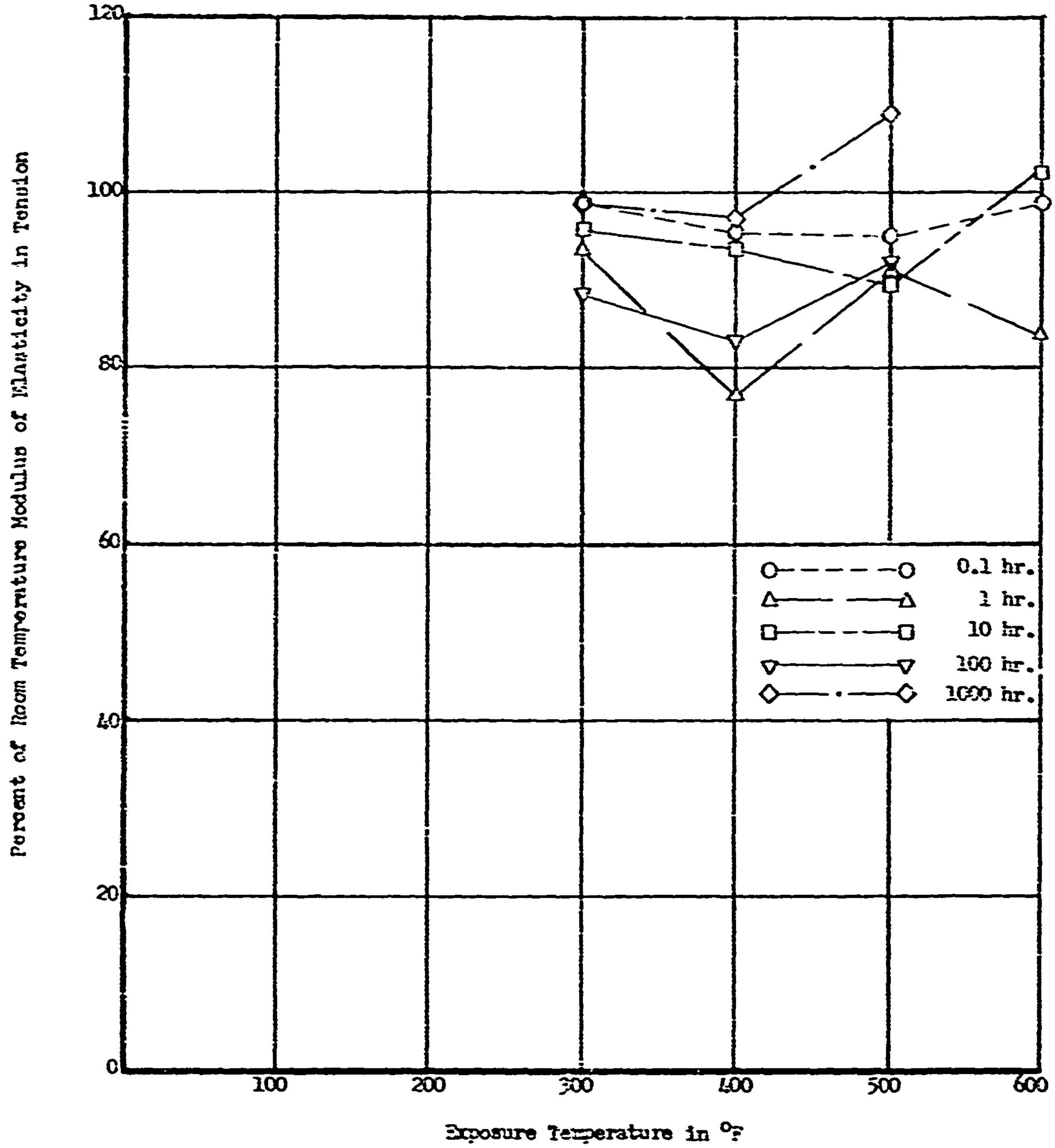

Figure 37. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

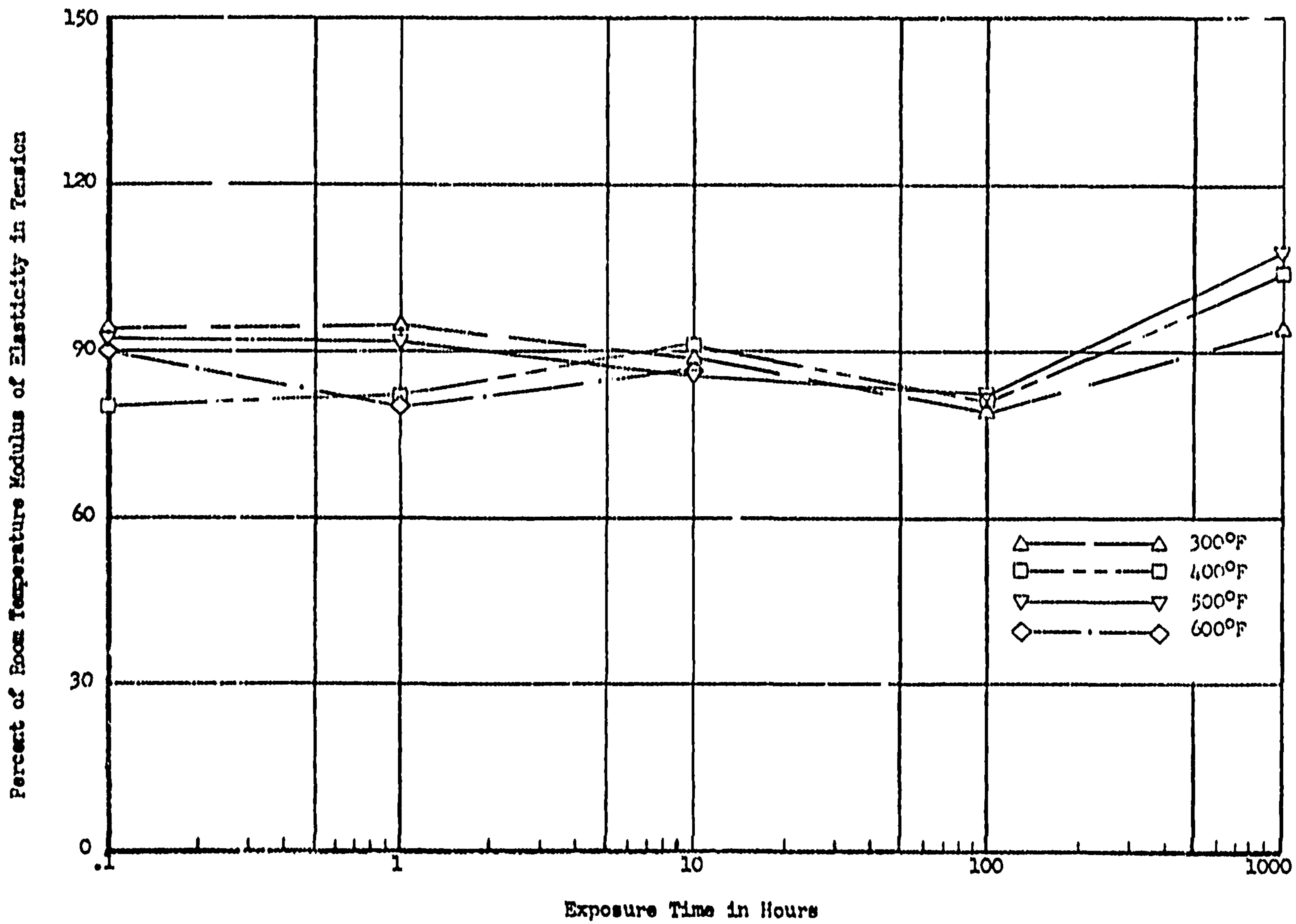

Figure 38. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

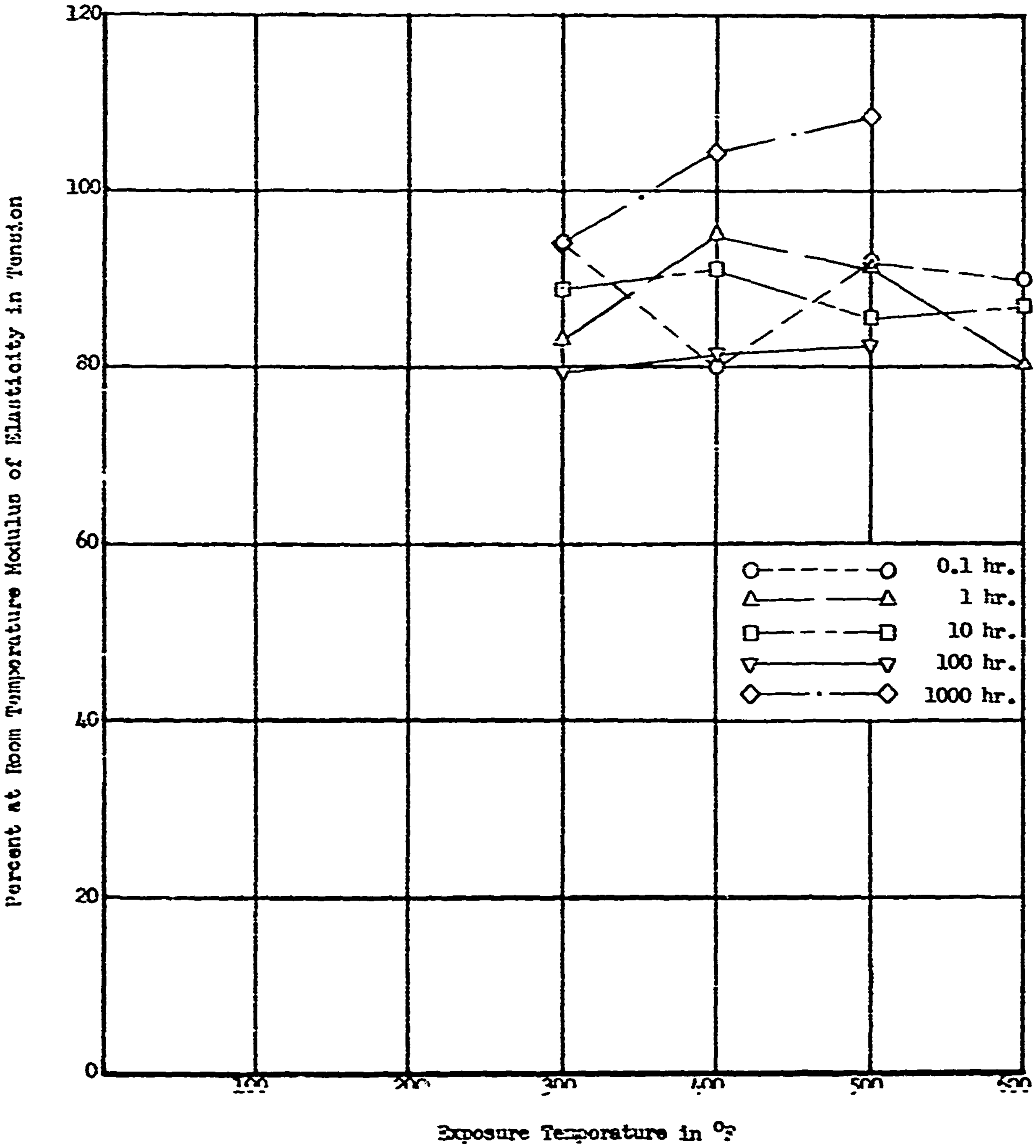

Figure 39. Modulus of Elasticity in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

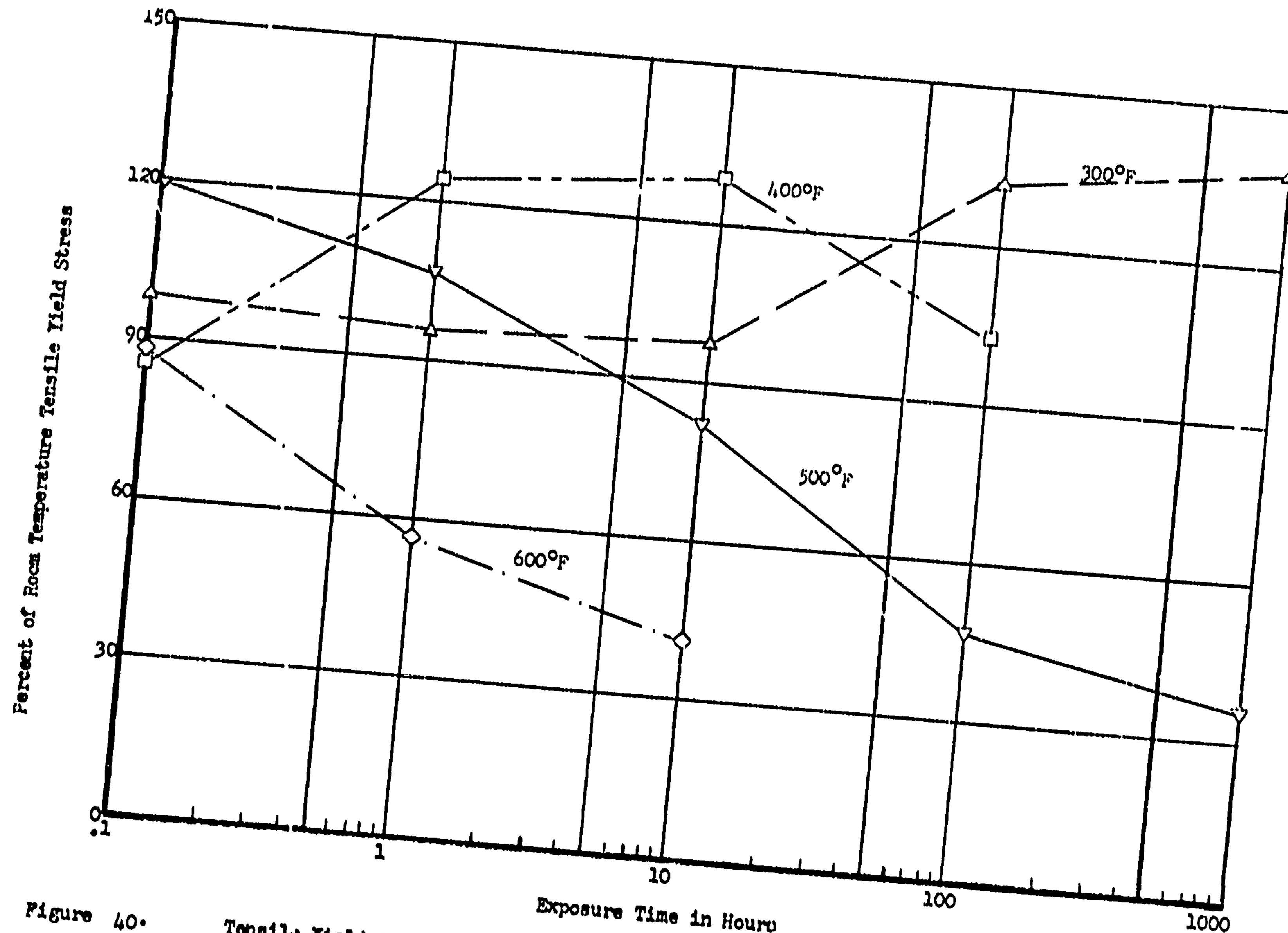

Figure 40. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

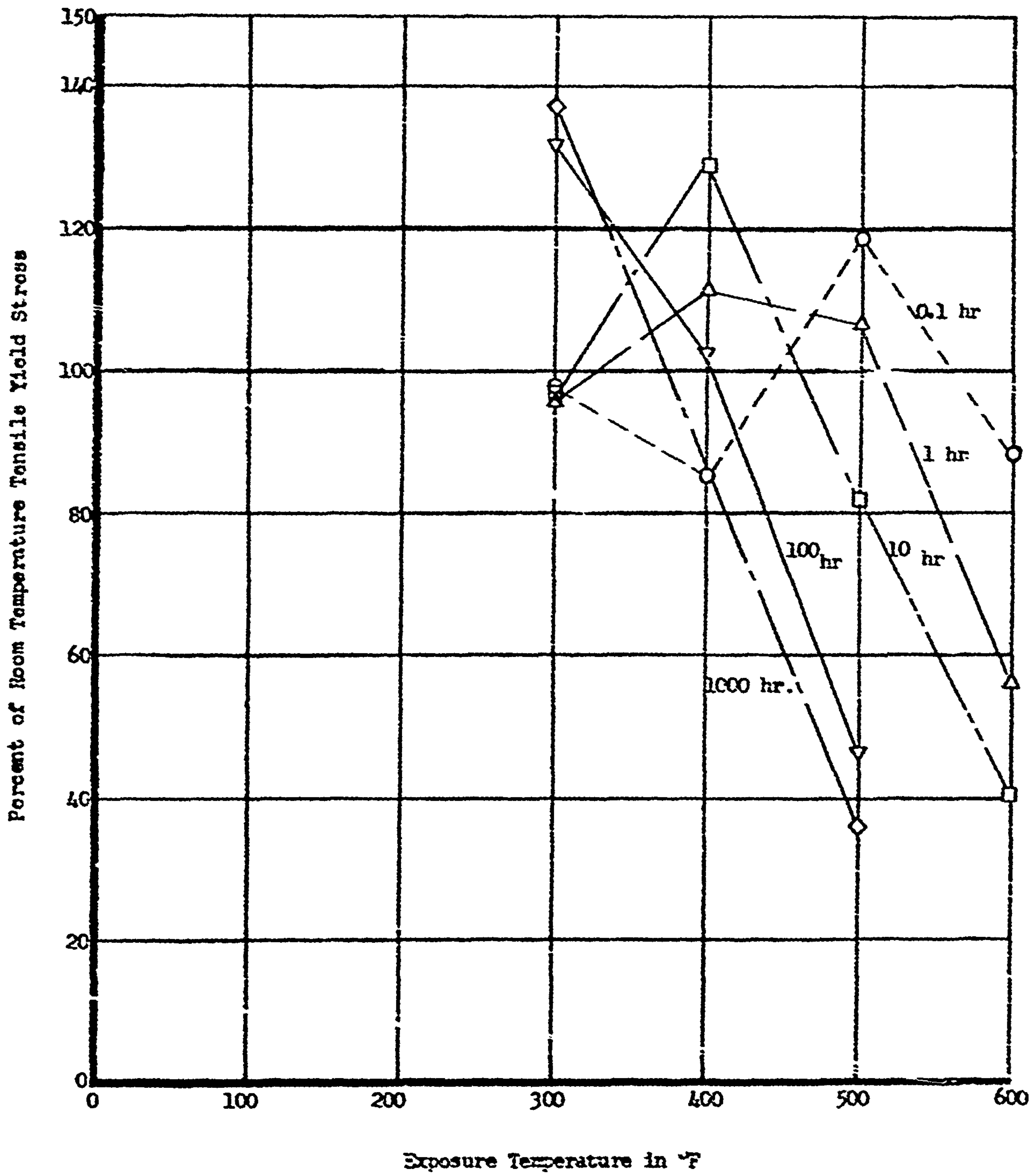

Figure 41. Tensile Yield Stress of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

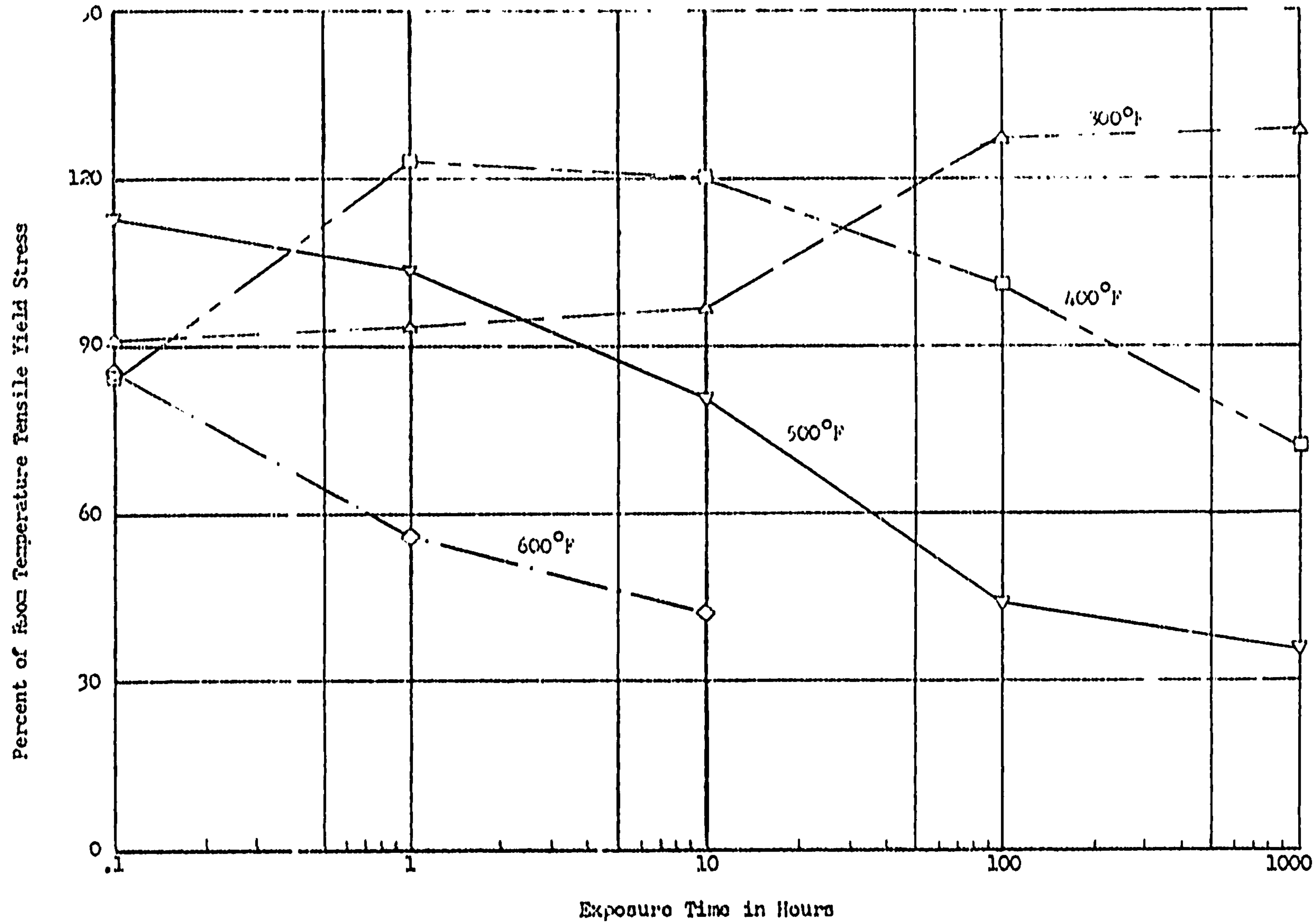

Figure 42. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

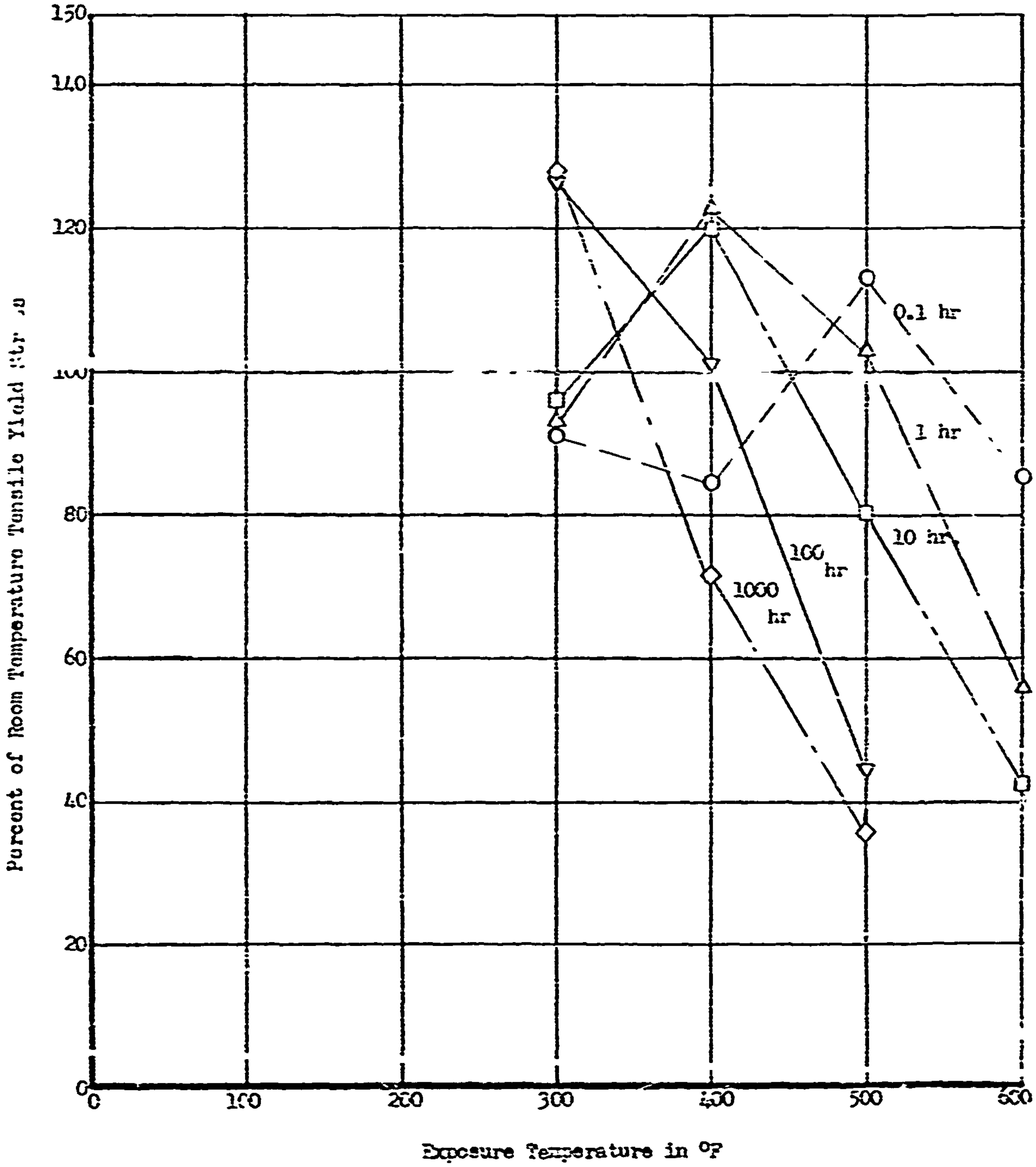

Figure 43. Tensile Yield Stress of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

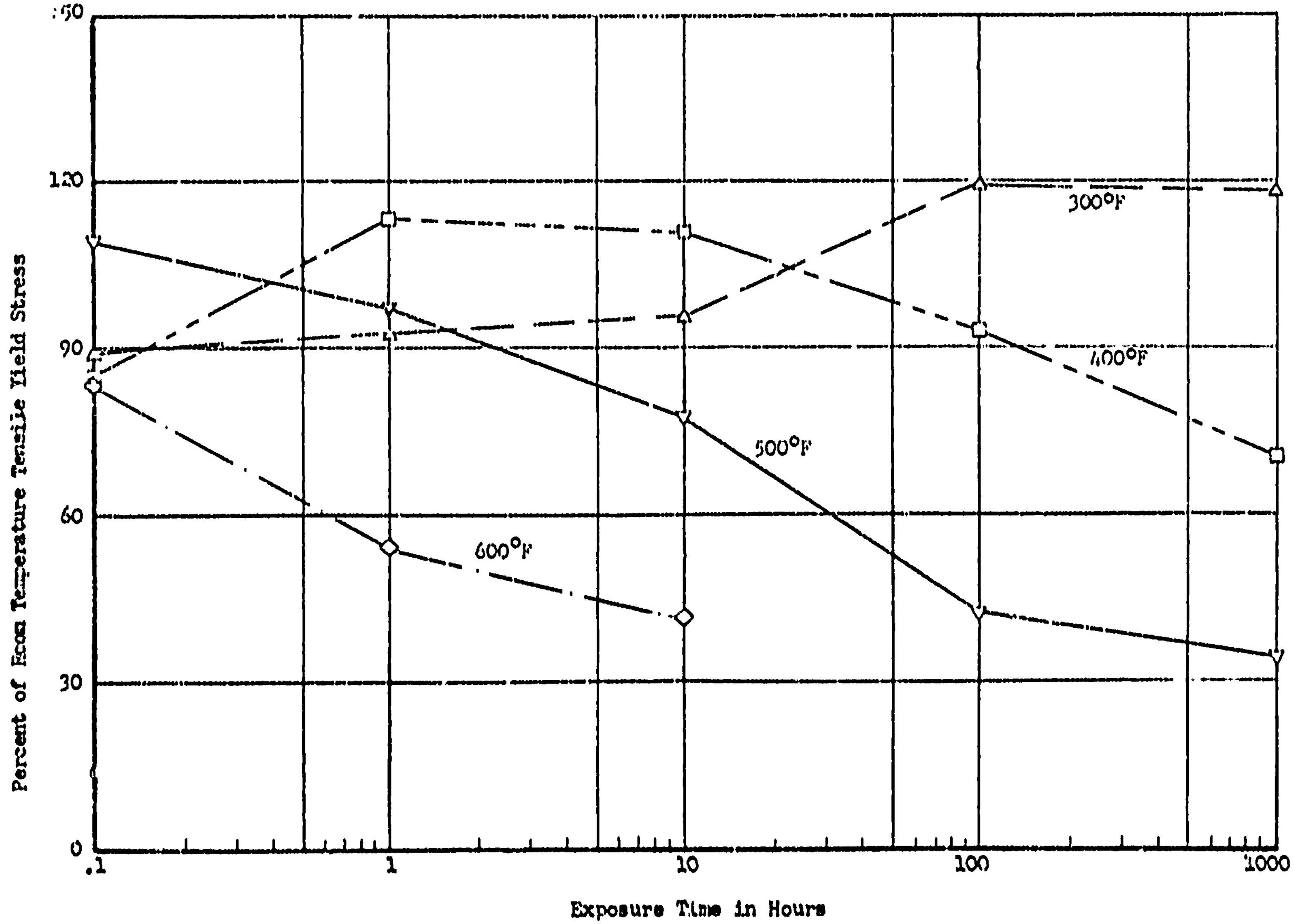

Figure 44. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

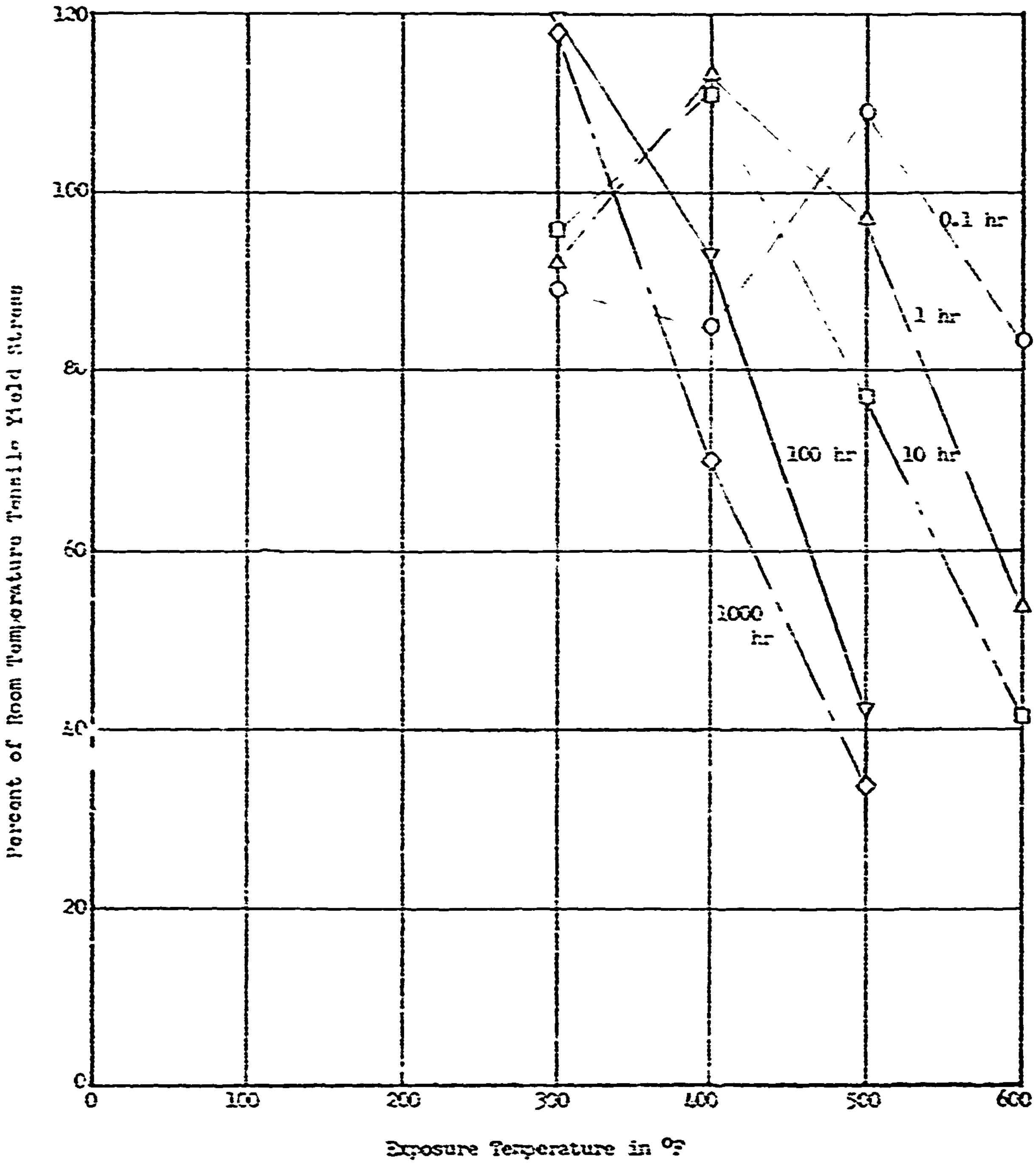

Figure 45. Tensile Yield Stress of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

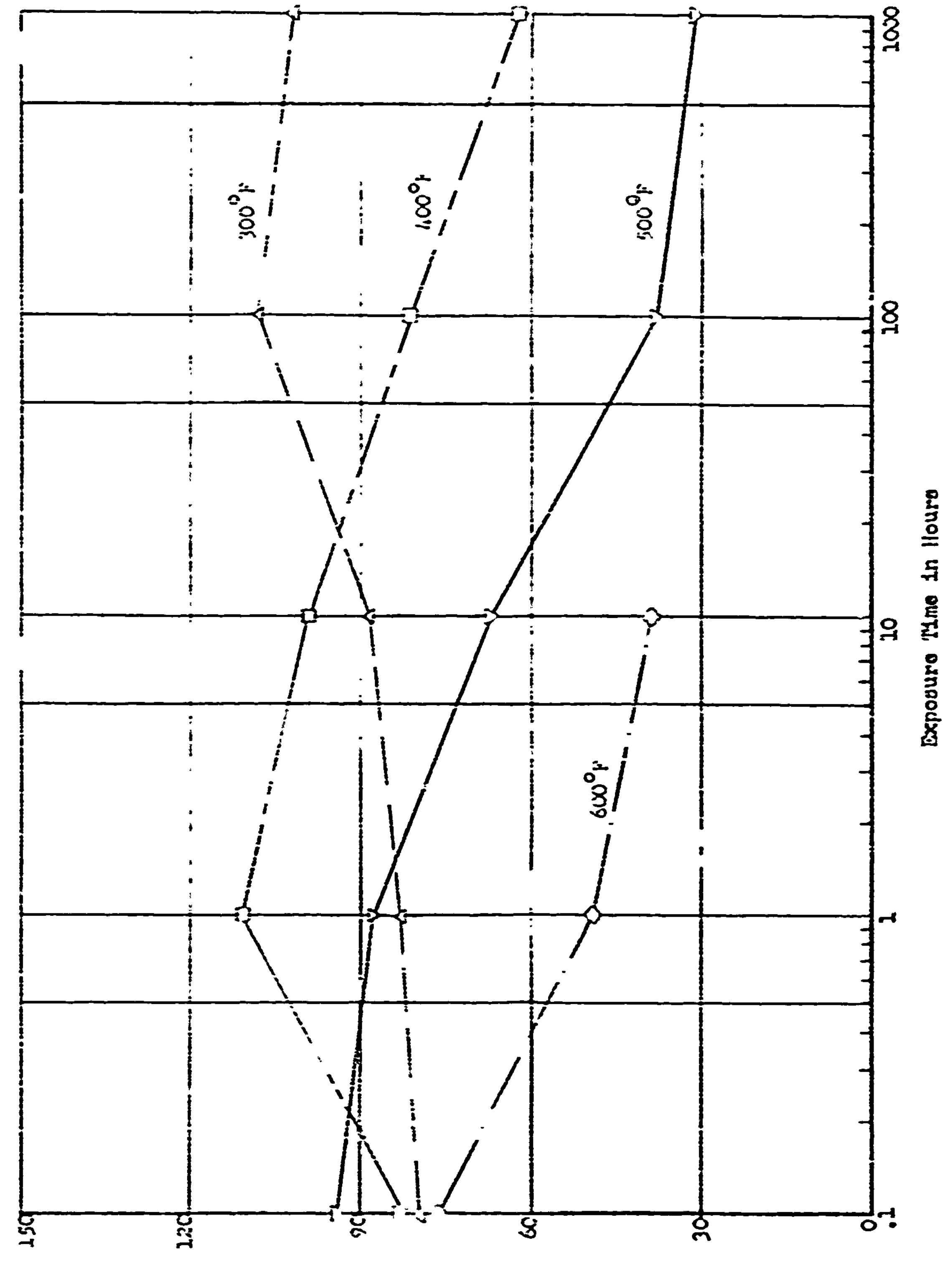

Figure 46. Tensile Yield Stress in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

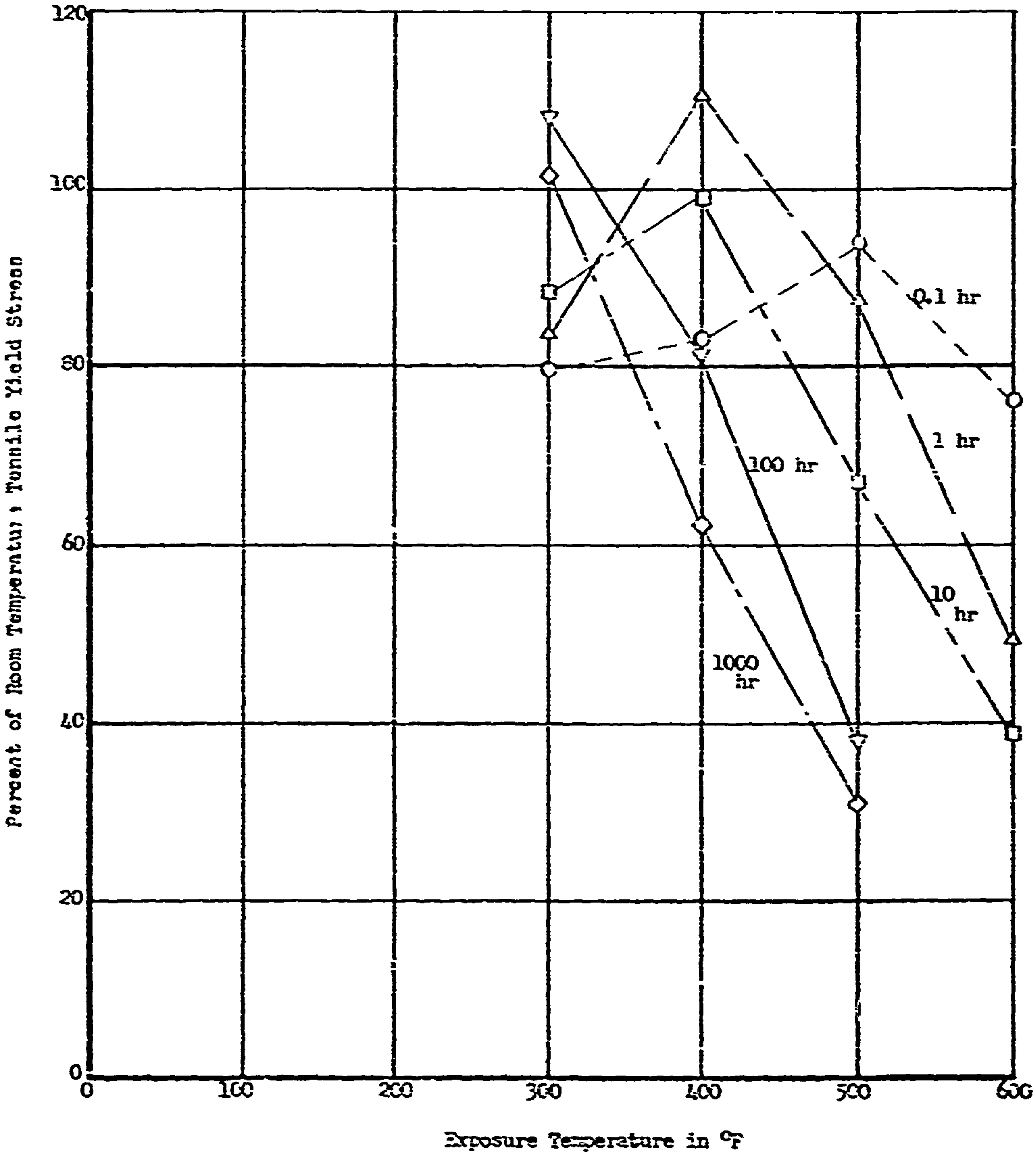

Figure 47. Tensile Yield Stress of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

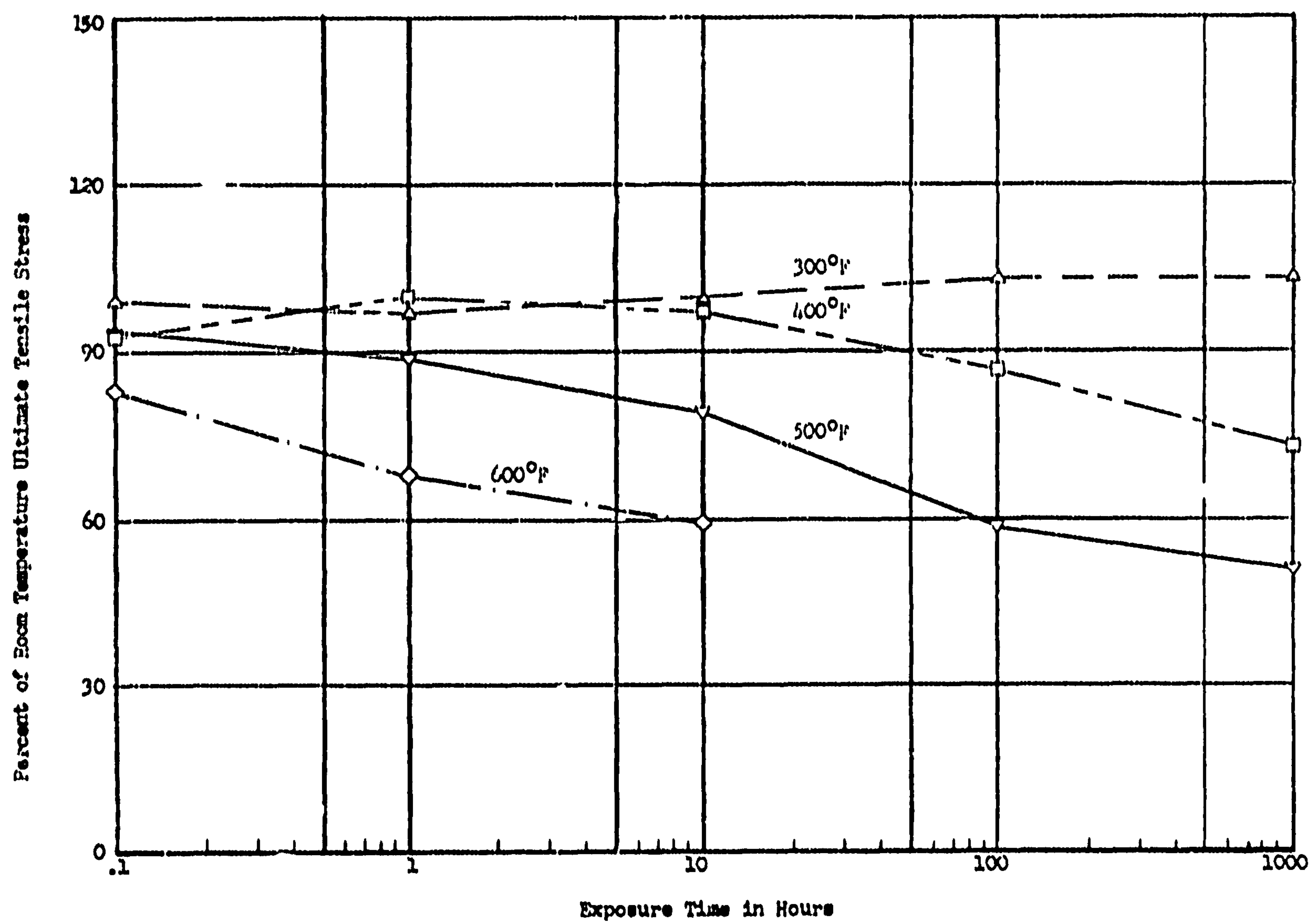

Figure 48. Ultimate Tensile Stress of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

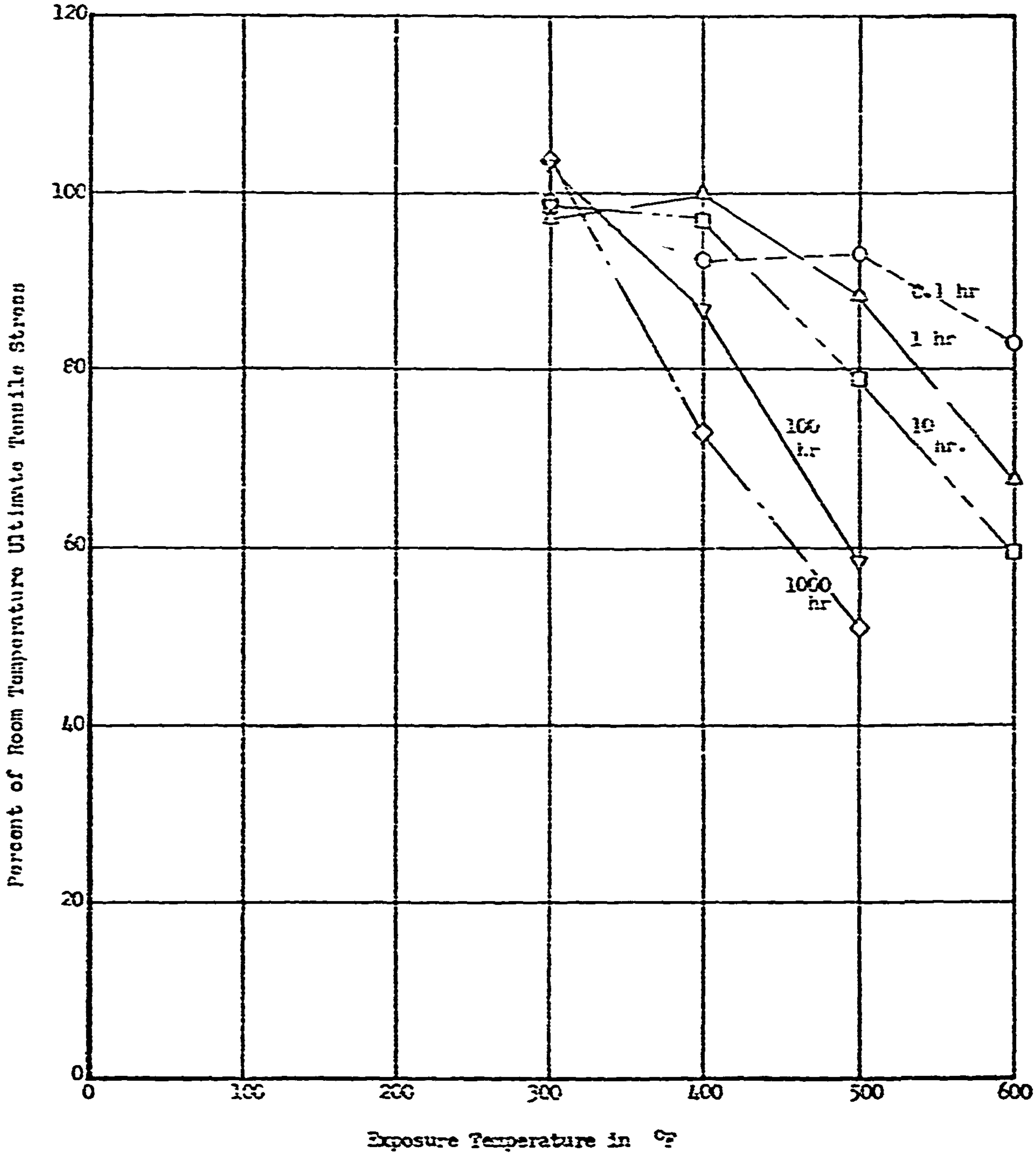

Figure 49. Ultimate Tensile Stress of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

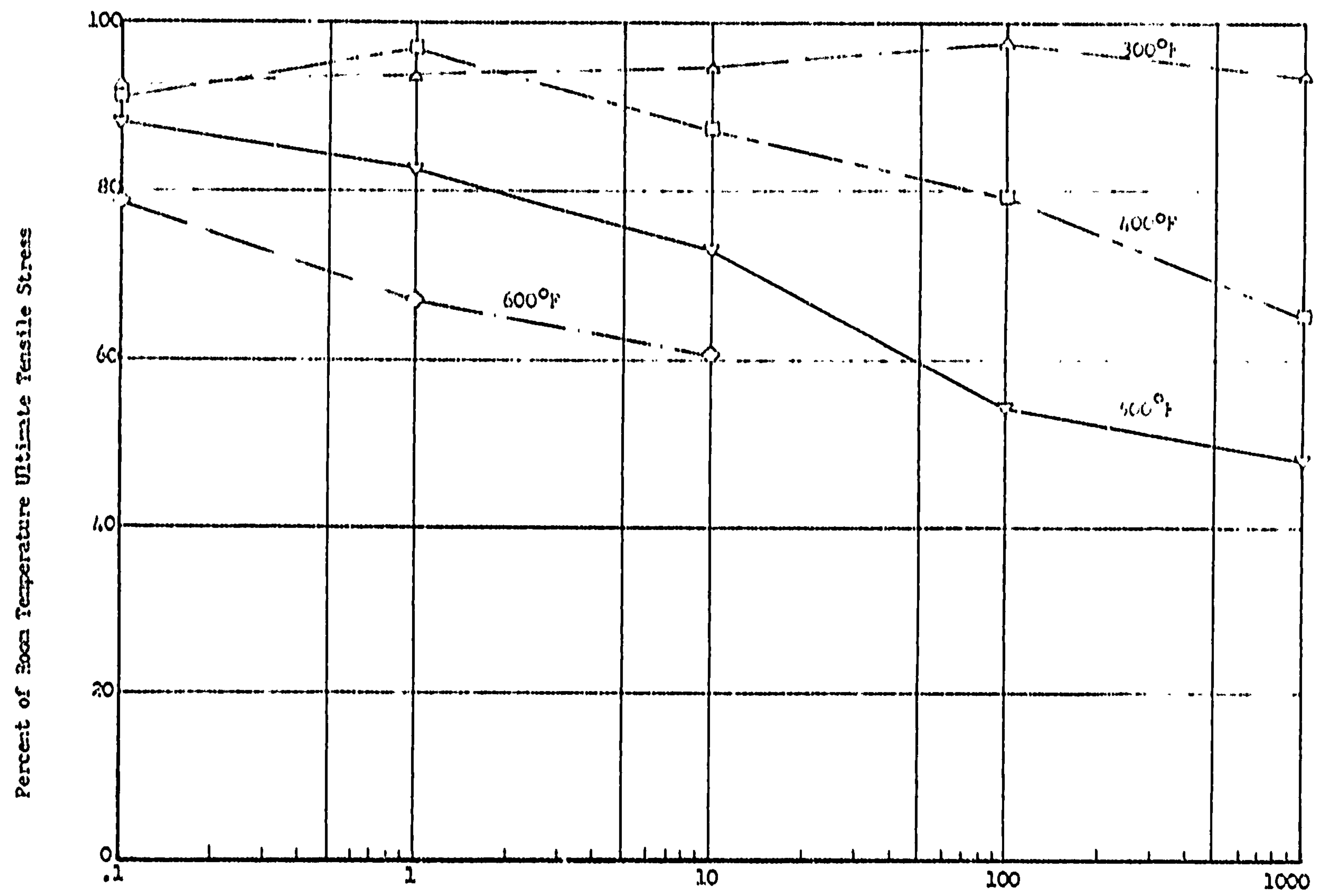

Figure 50. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

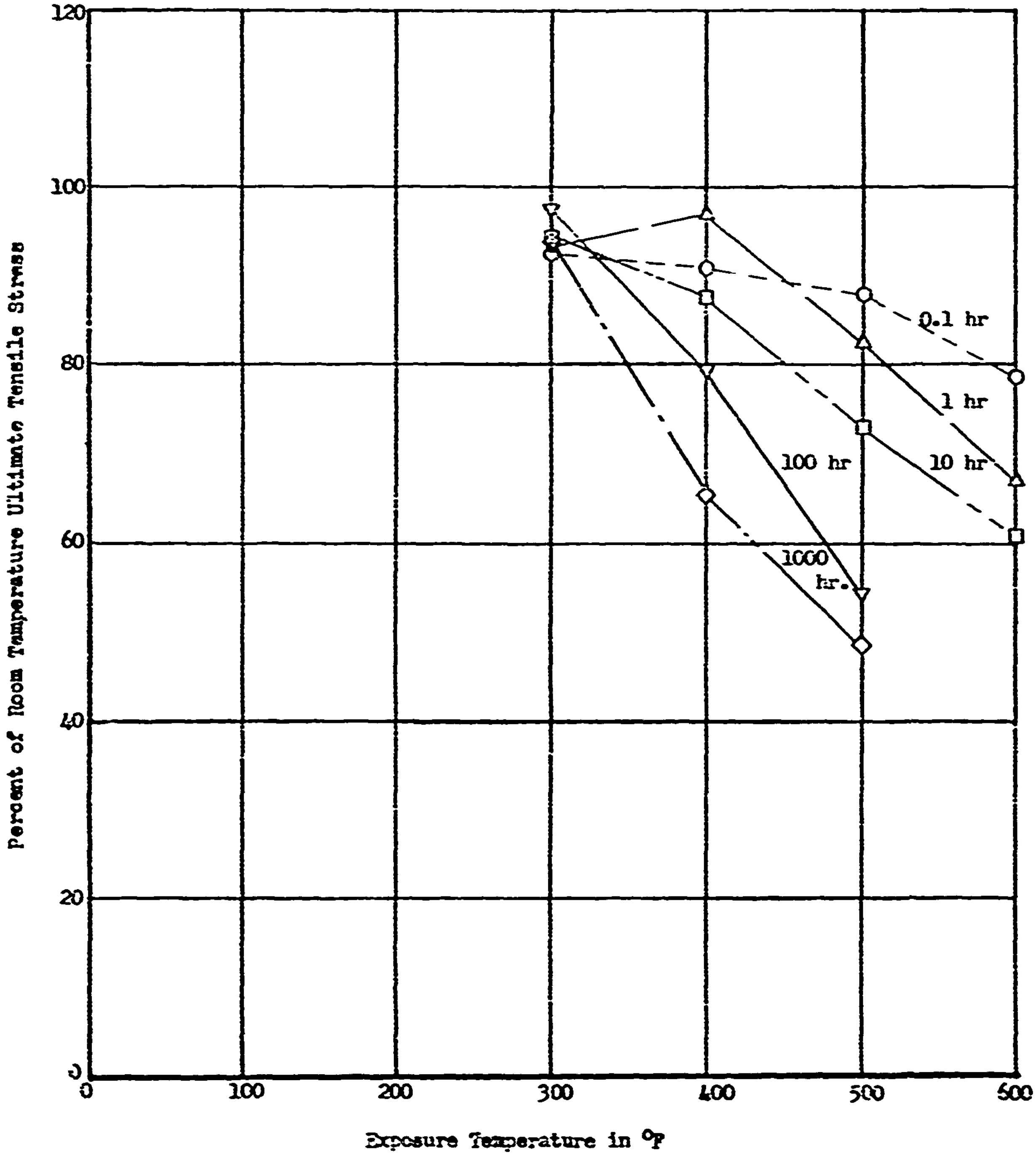

Figure 51. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

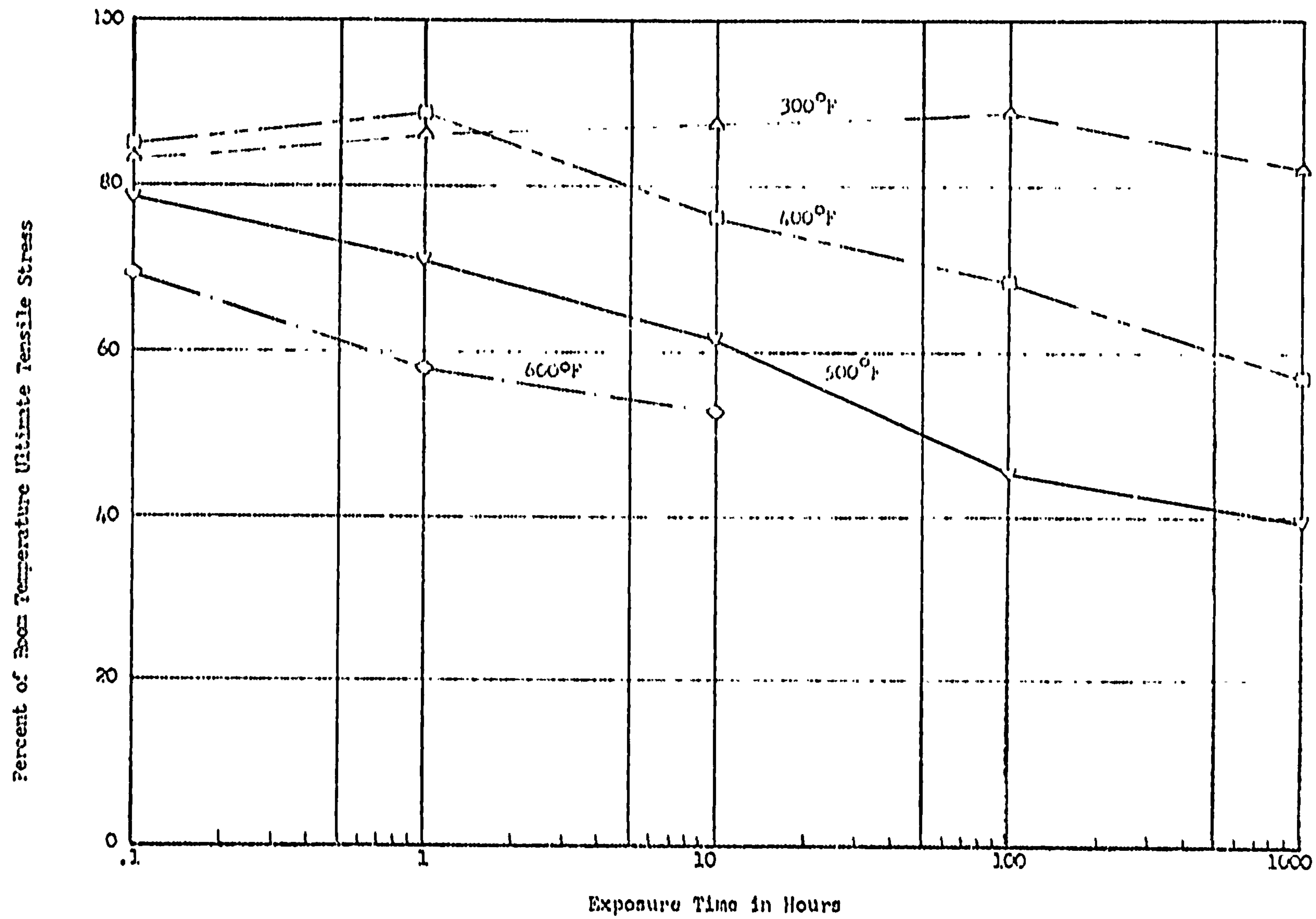

Figure 52. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

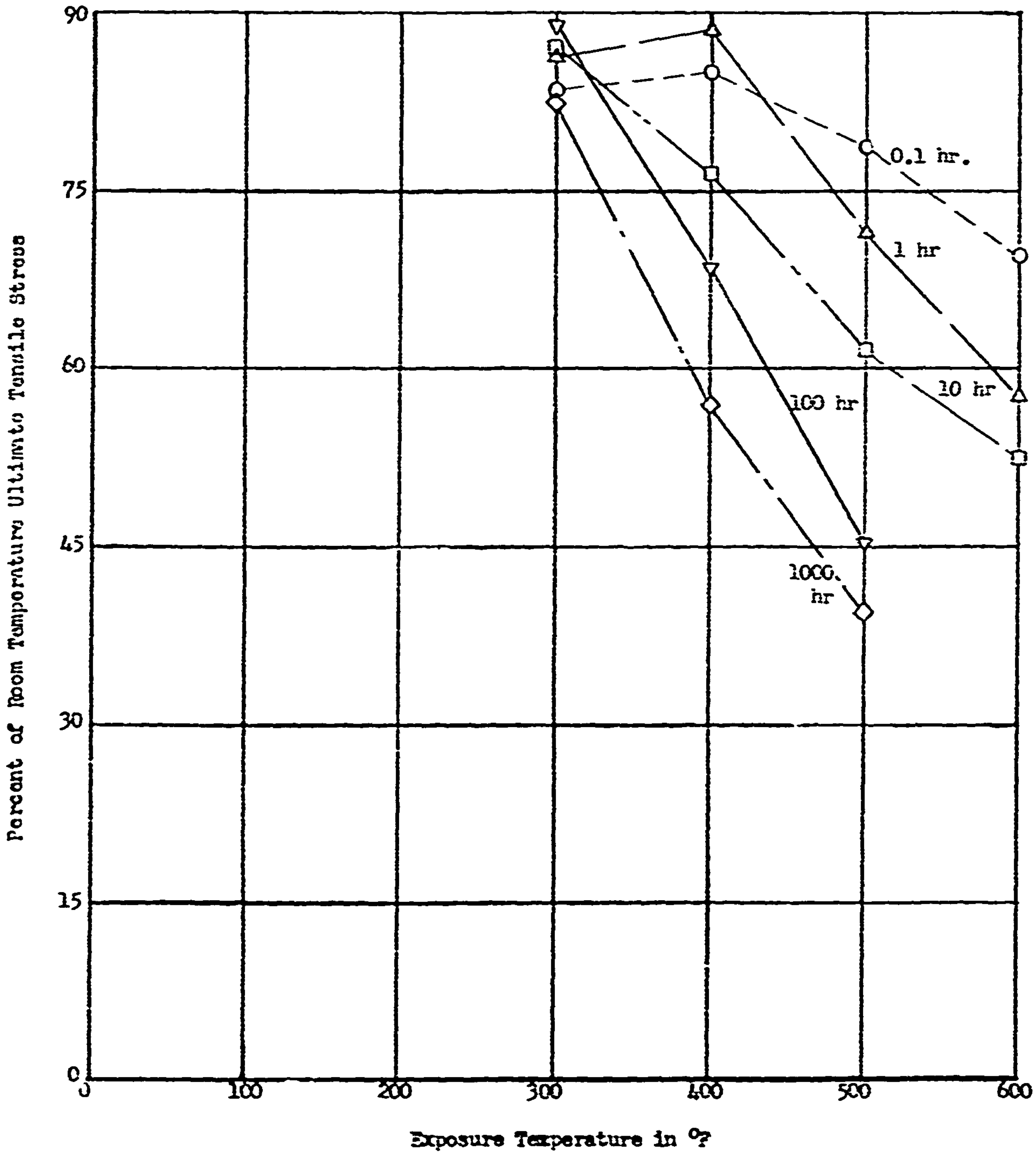

Figure 53. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

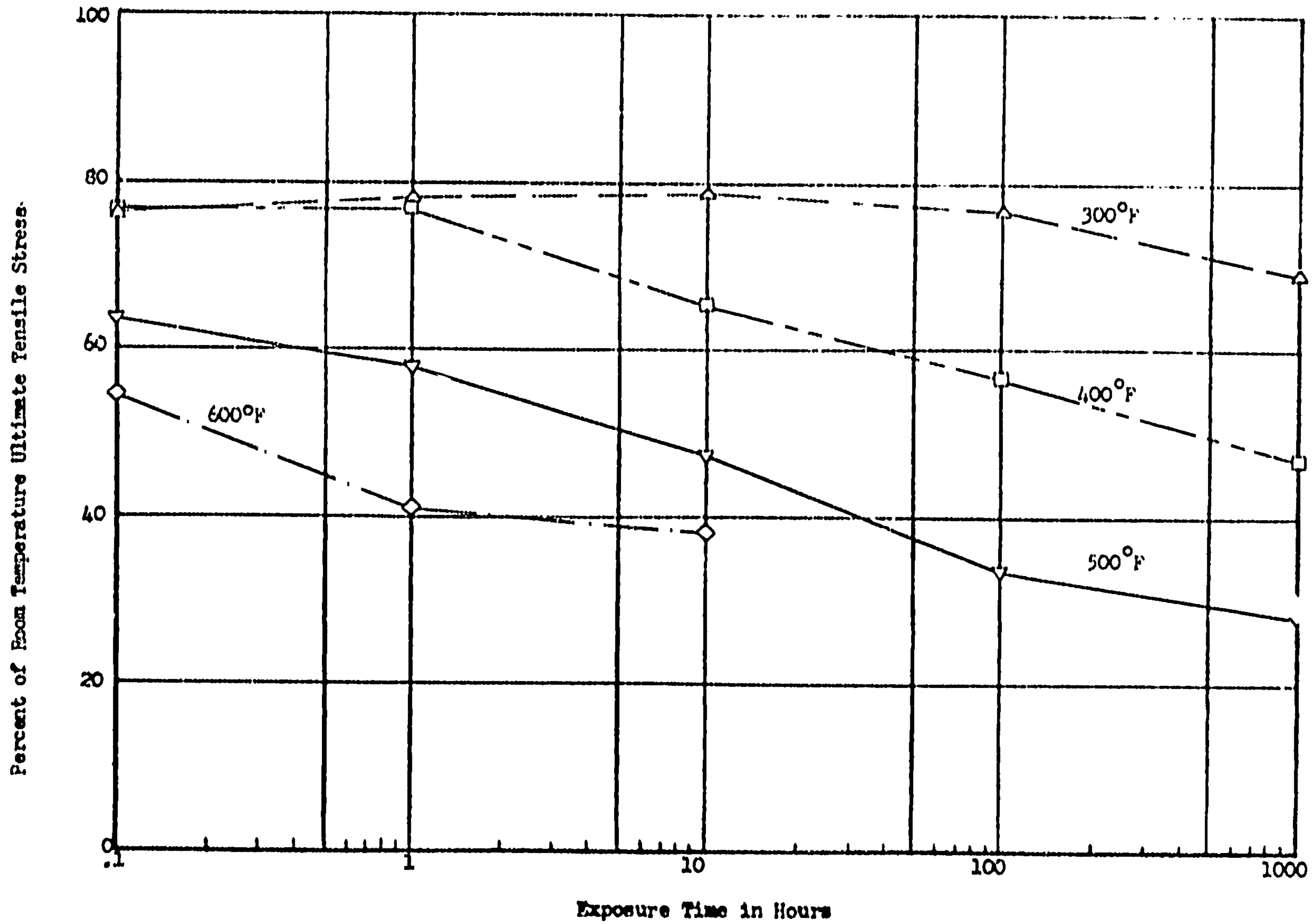

Figure 54. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

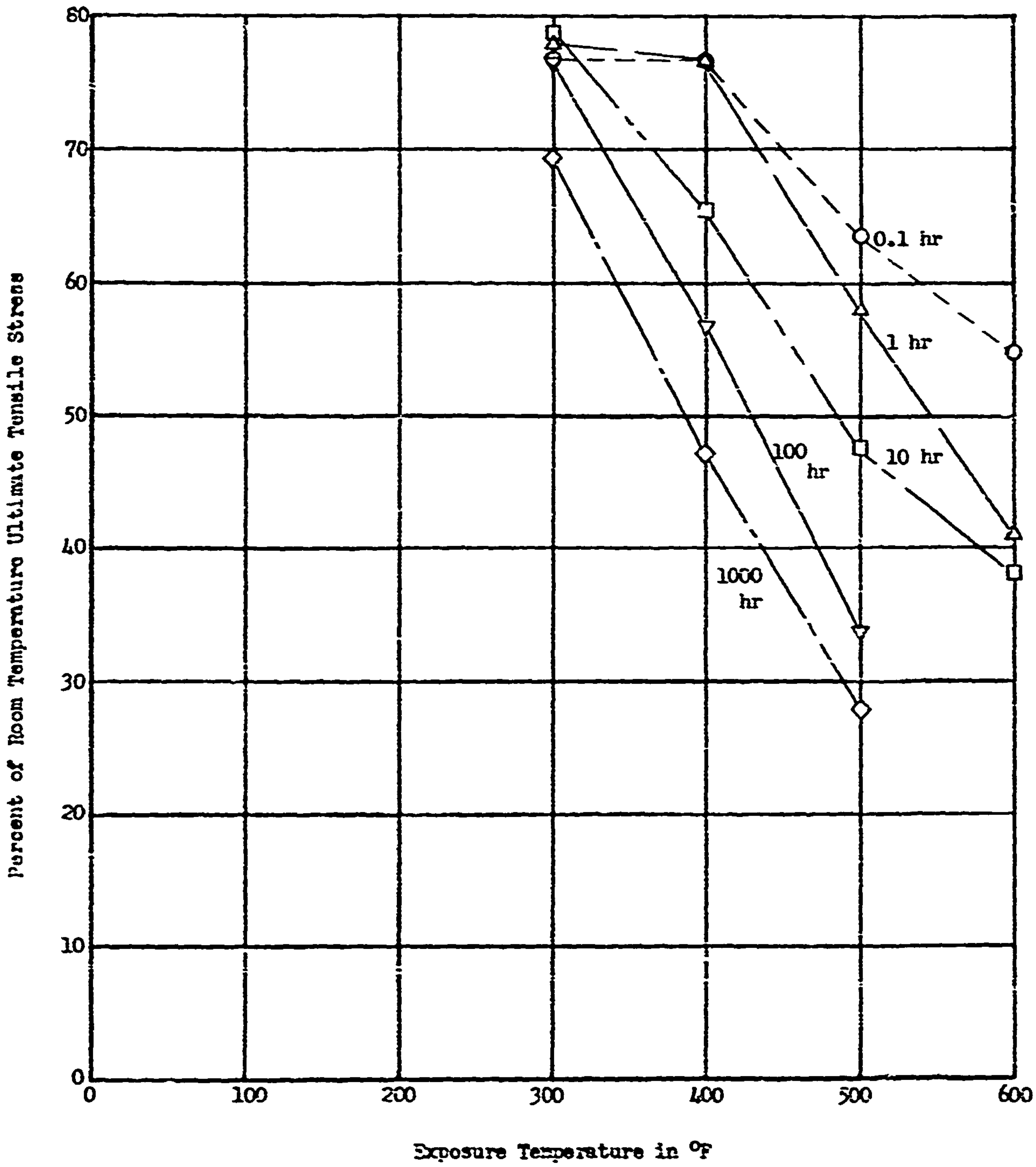

Figure 55. Ultimate Tensile Stress of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

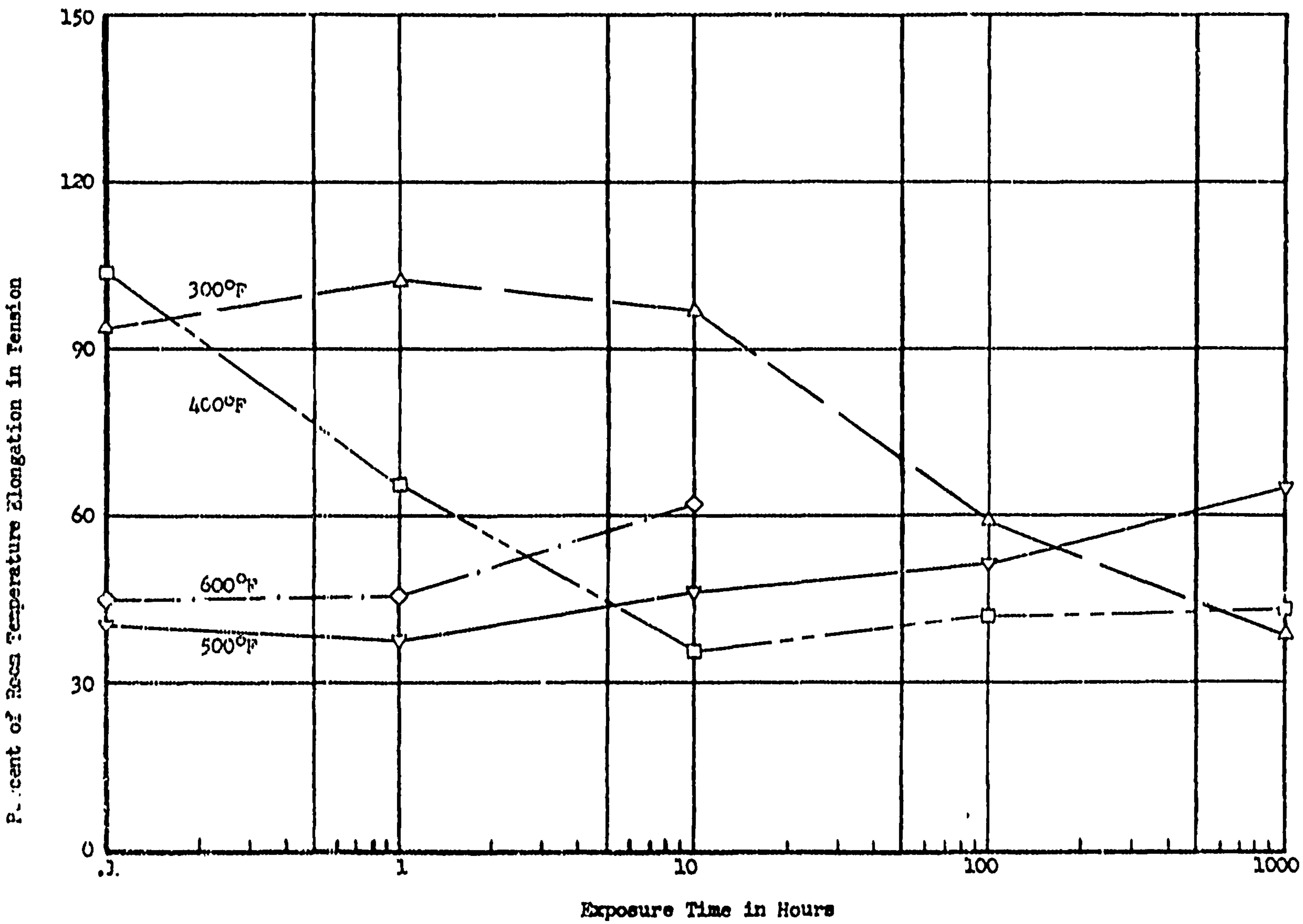

Figure 56. Elongation in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

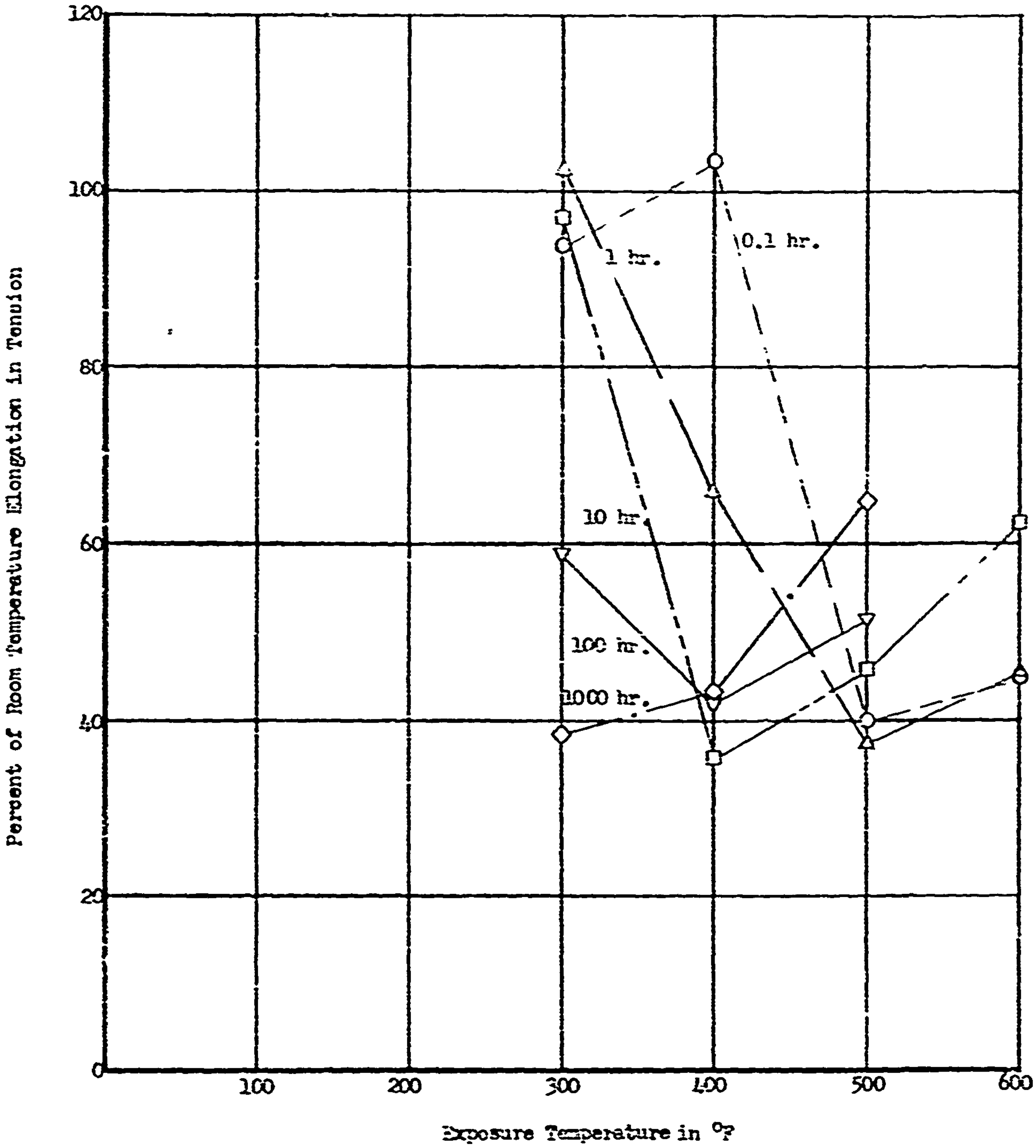

Figure 57. Elongation in Tension of 2024-T3 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

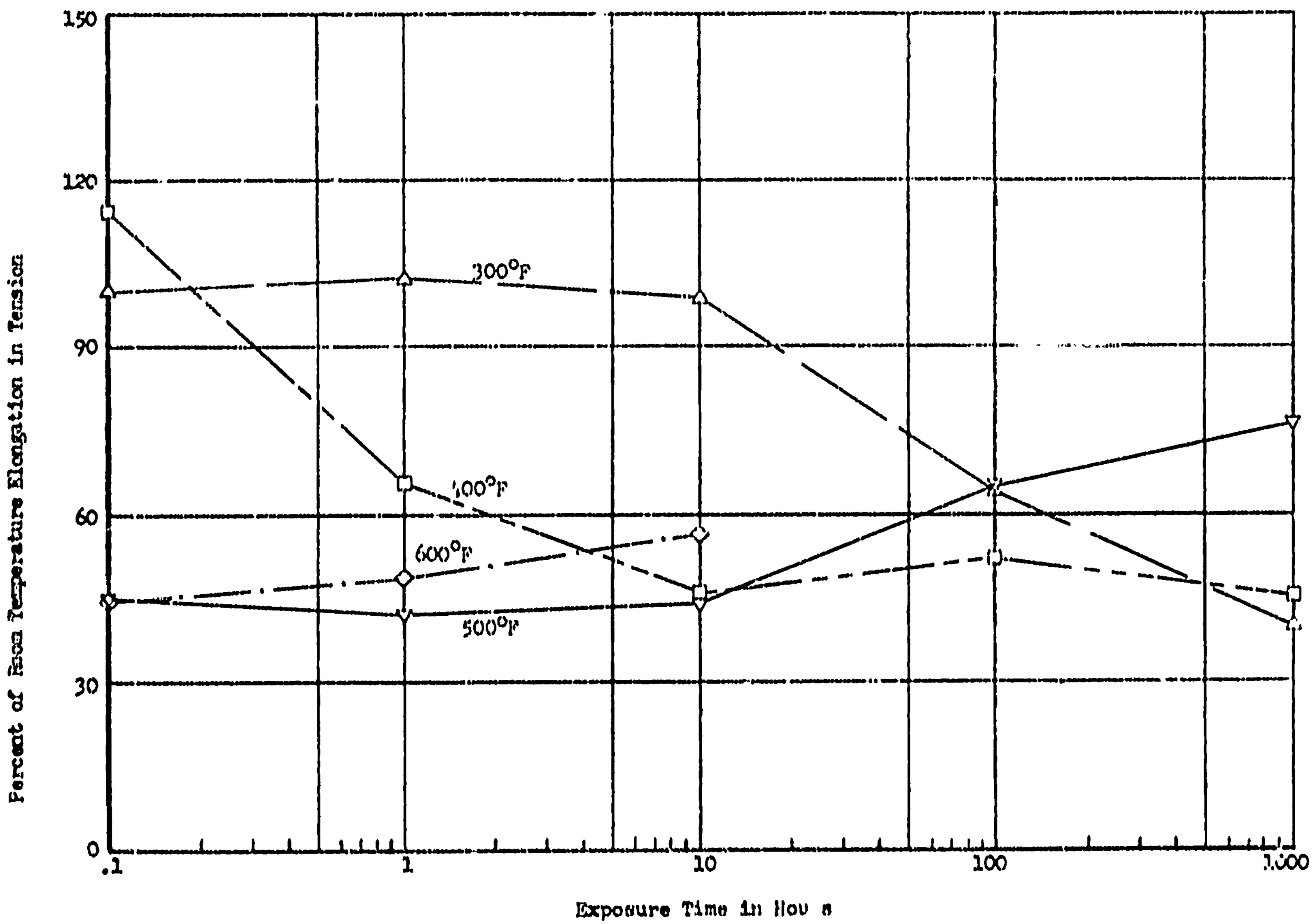

Figure 58. Elongation in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

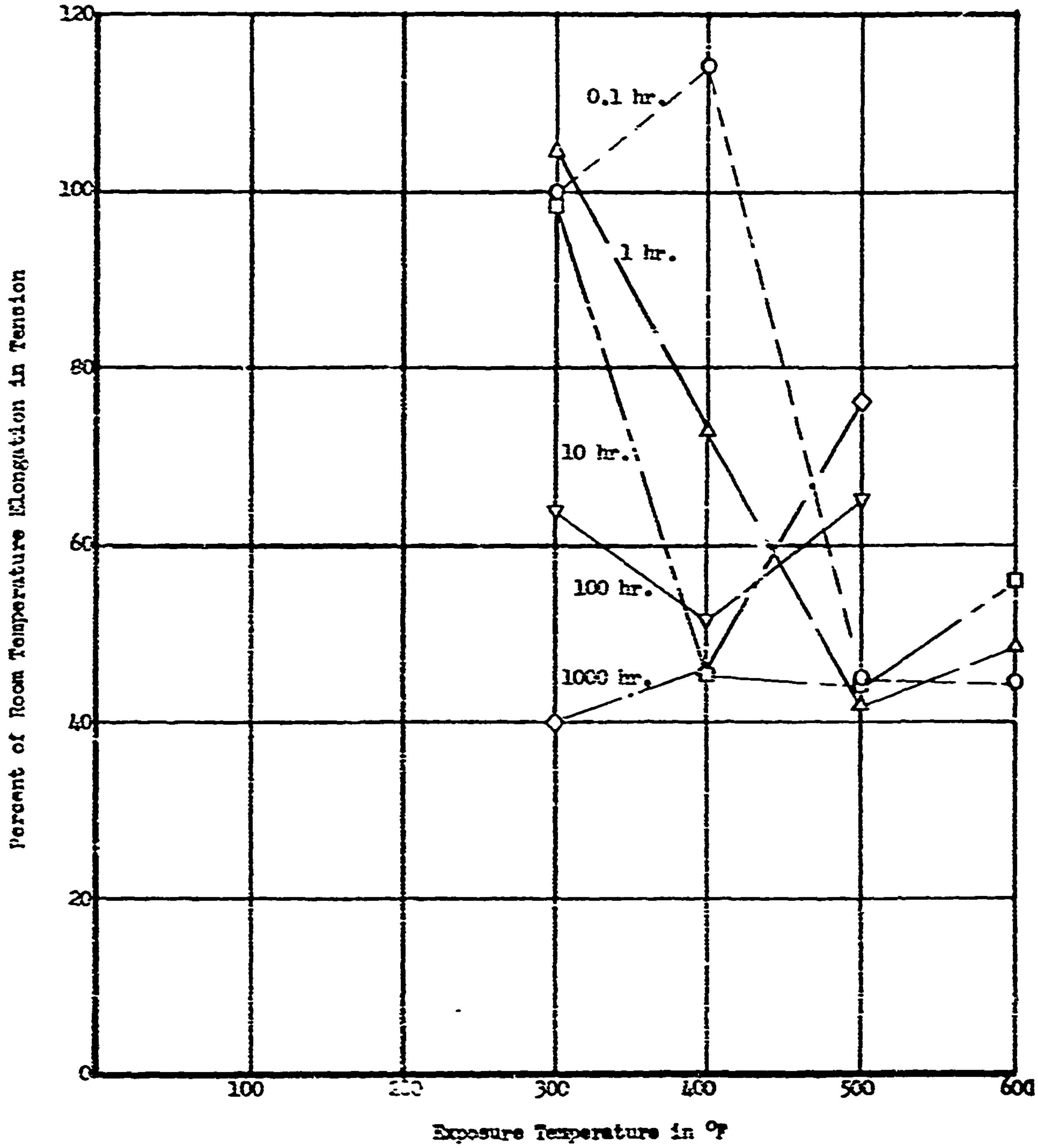

Figure 59. Elongation in Tension of 2024-T3 Clad Sheet at 200°F After Exposure to Elevated Temperatures

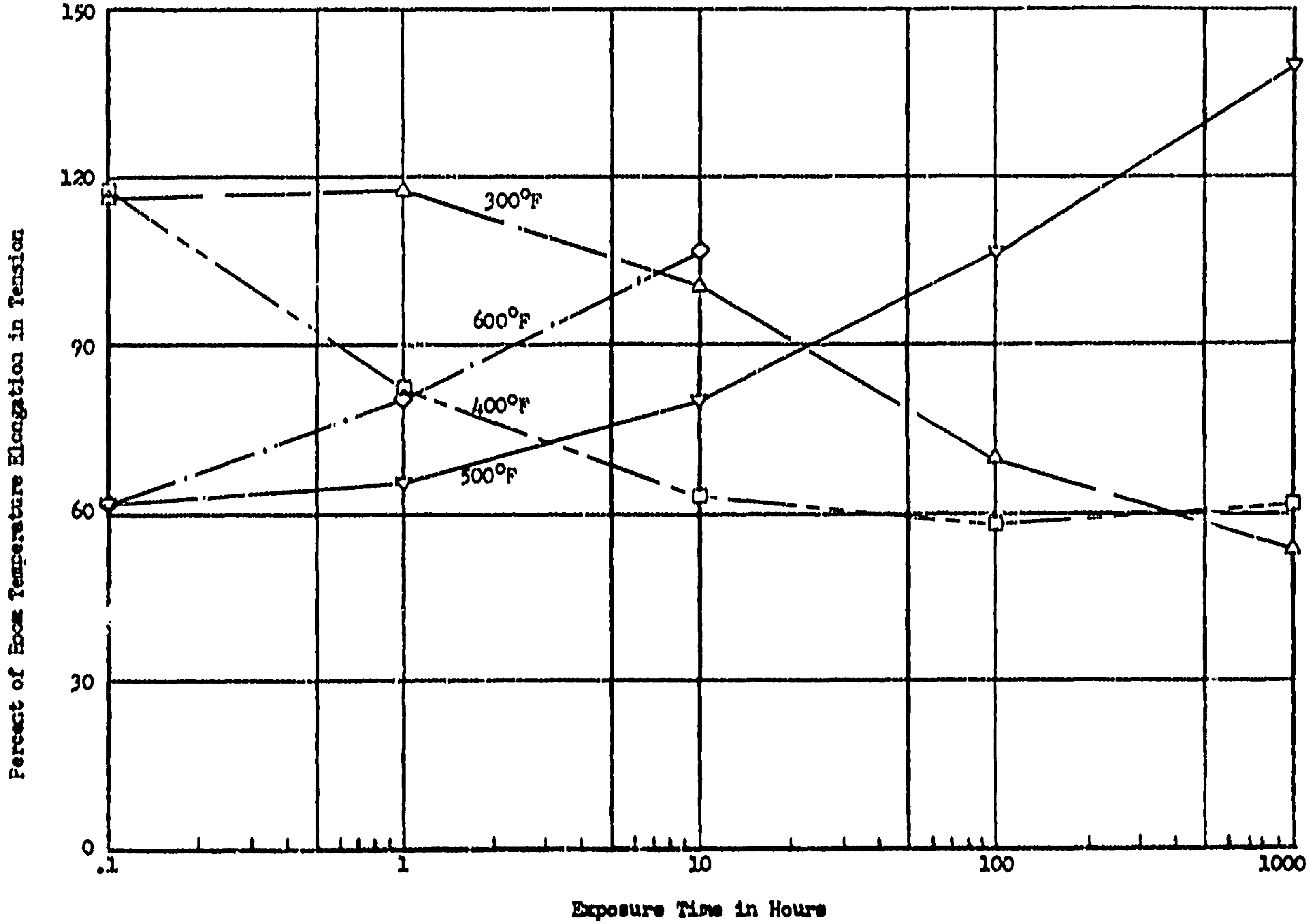

Figure 60. Elongation in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

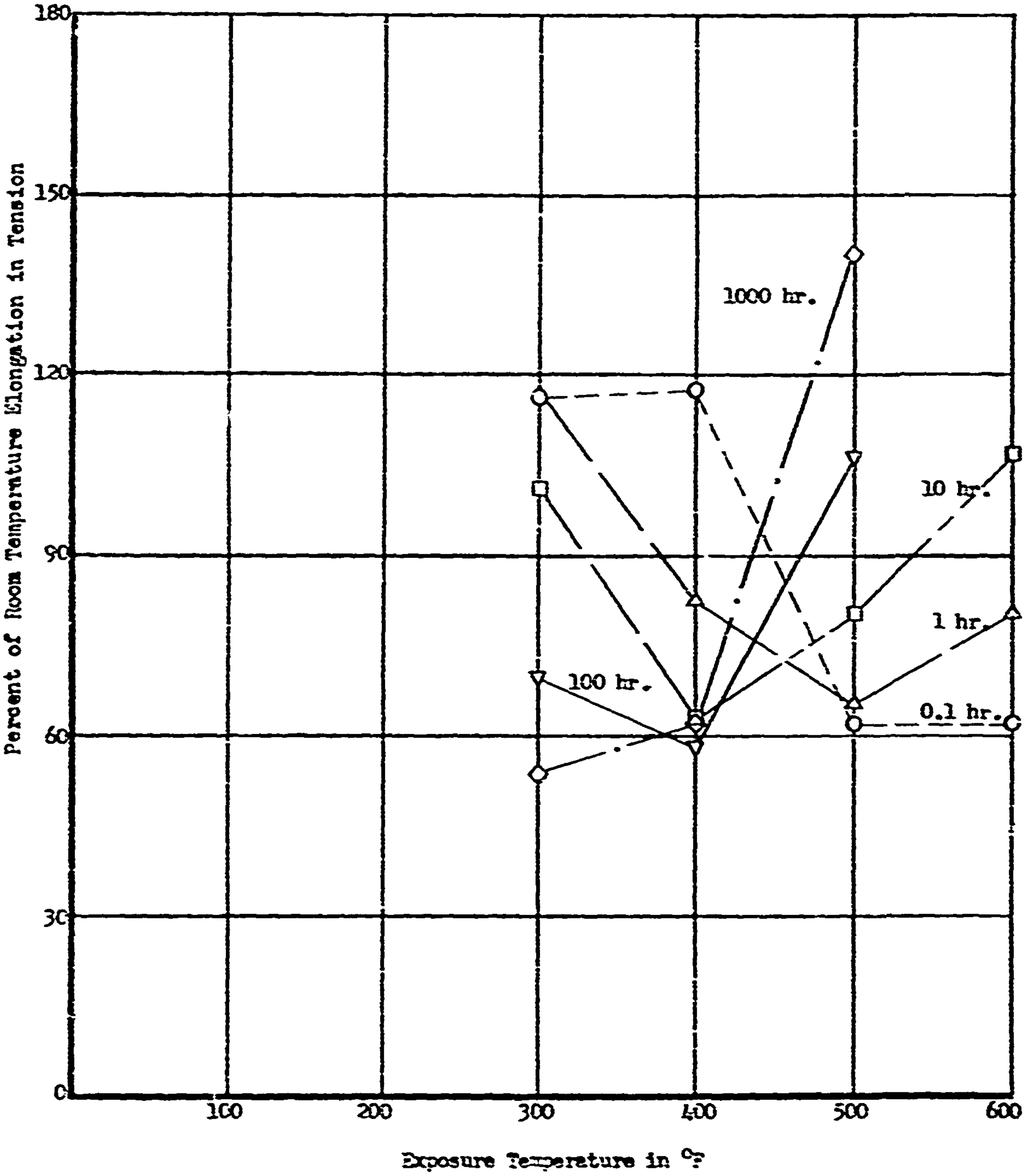

Figure 61. Elongation in Tension of 2024-T3 Clad Sheet at 300°F After Exposure to Elevated Temperatures

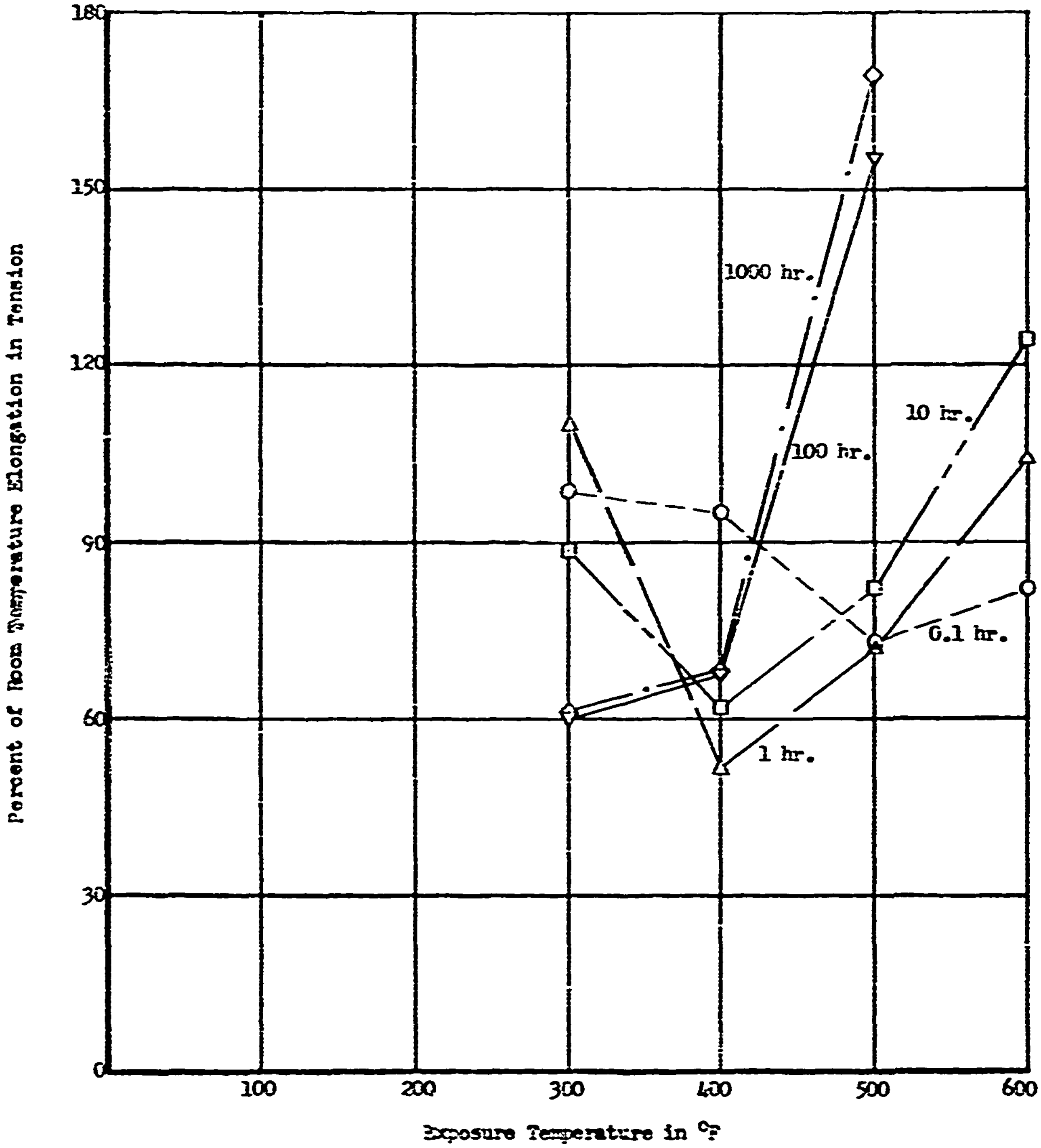

Figure 62. Elongation in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

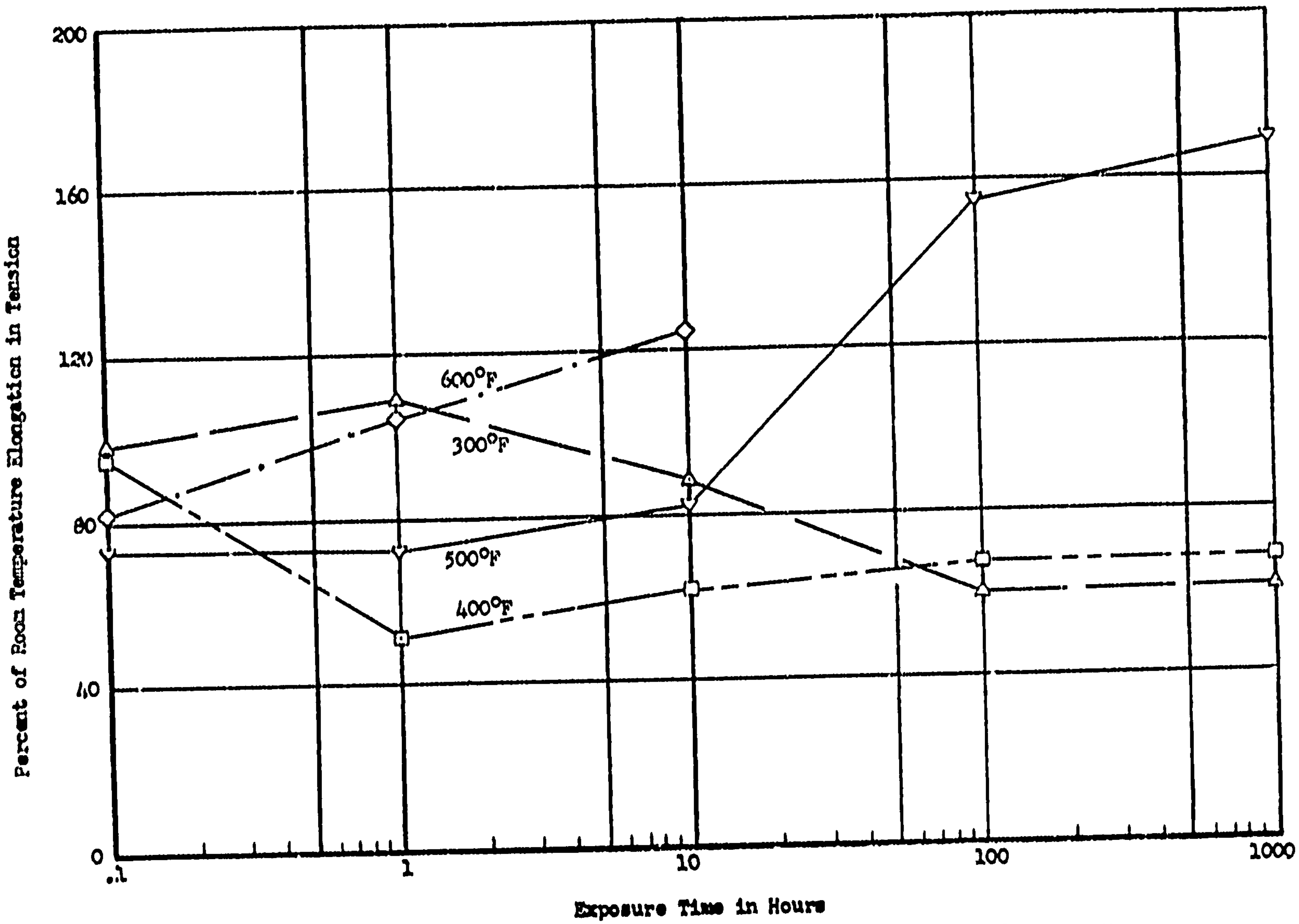

Figure 63. Elongation in Tension of 2024-T3 Clad Sheet at 400°F After Exposure to Elevated Temperatures

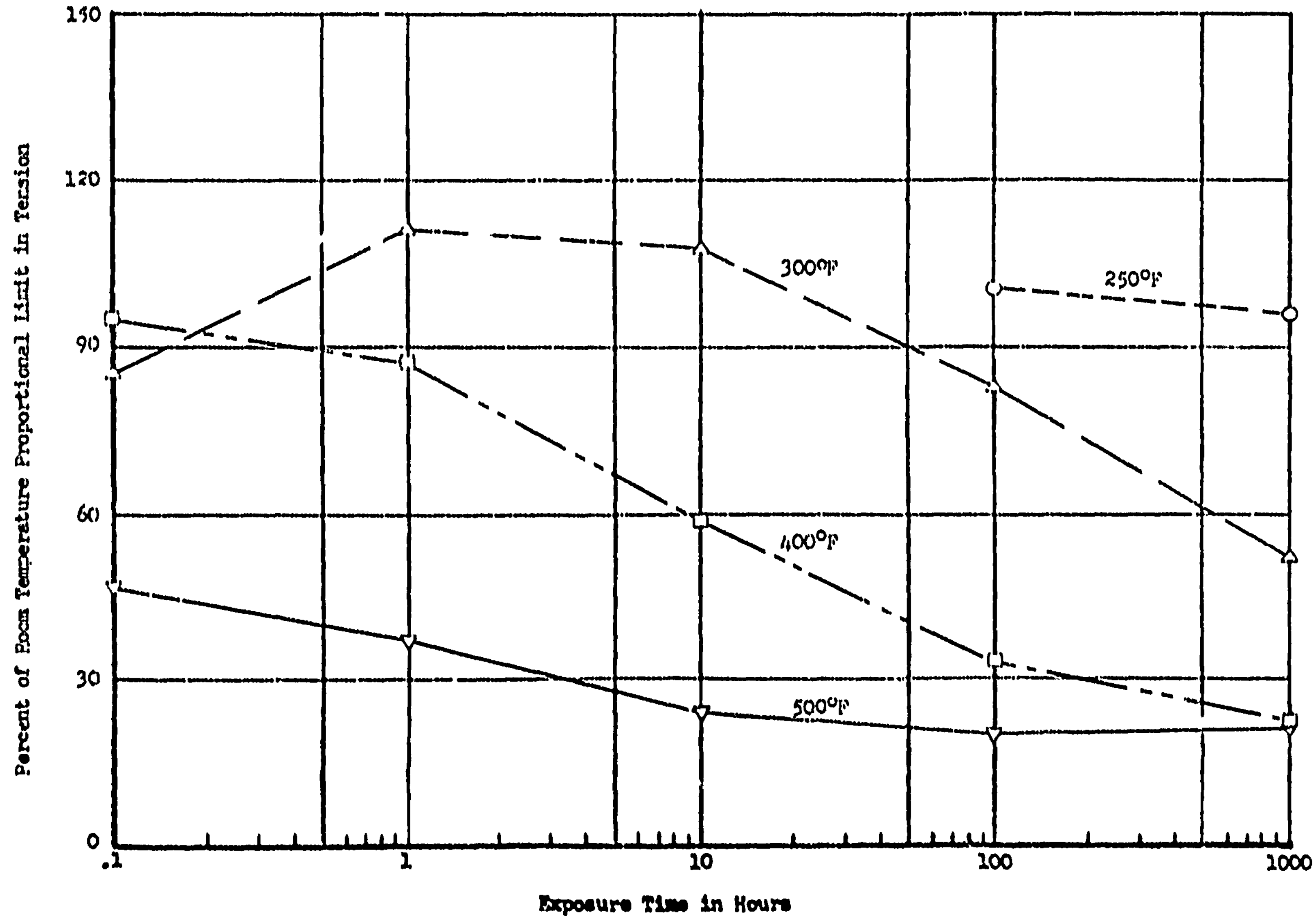

Figure 64. Proportional Limit in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

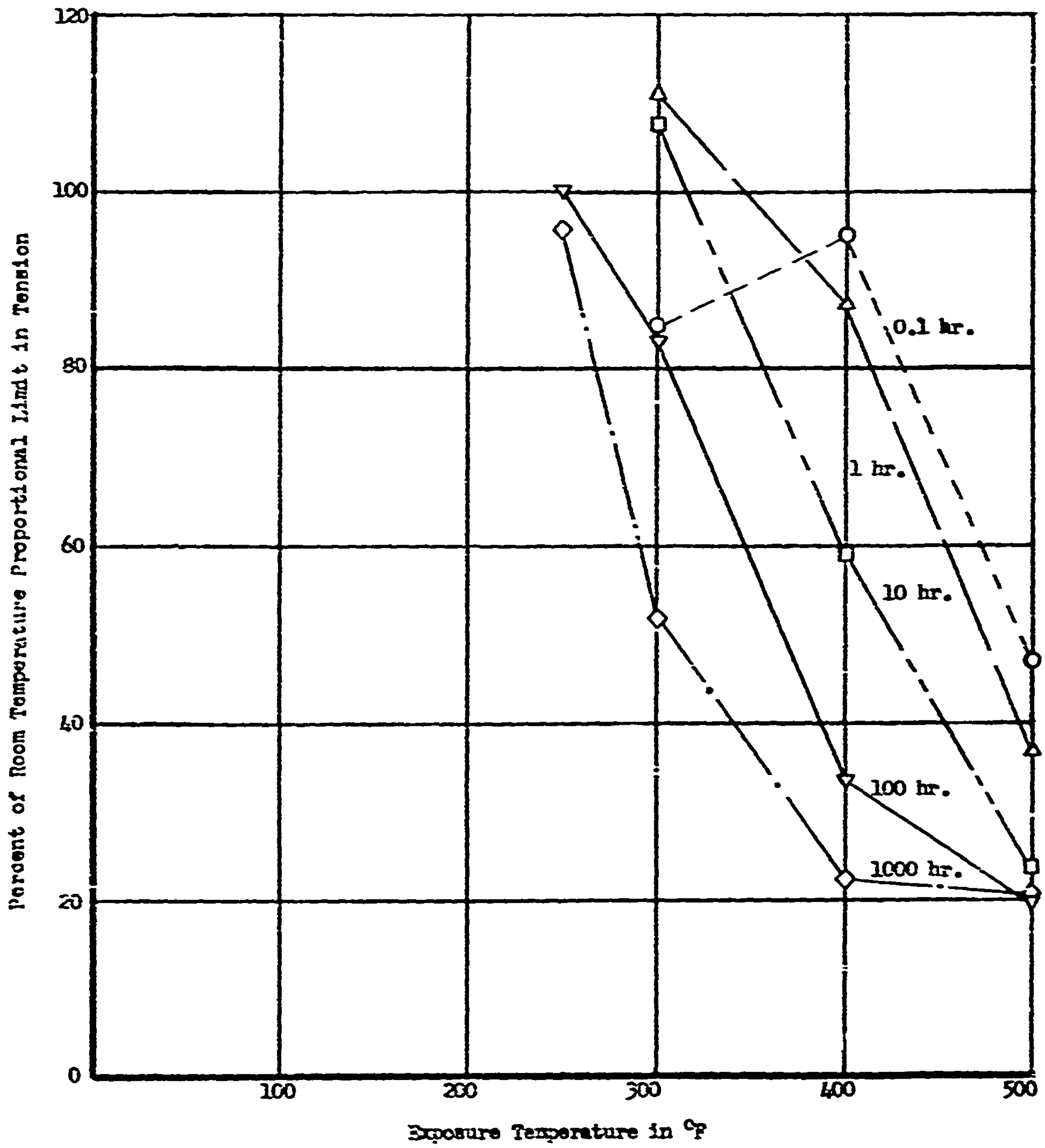

Figure 65. Proportional Limit in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

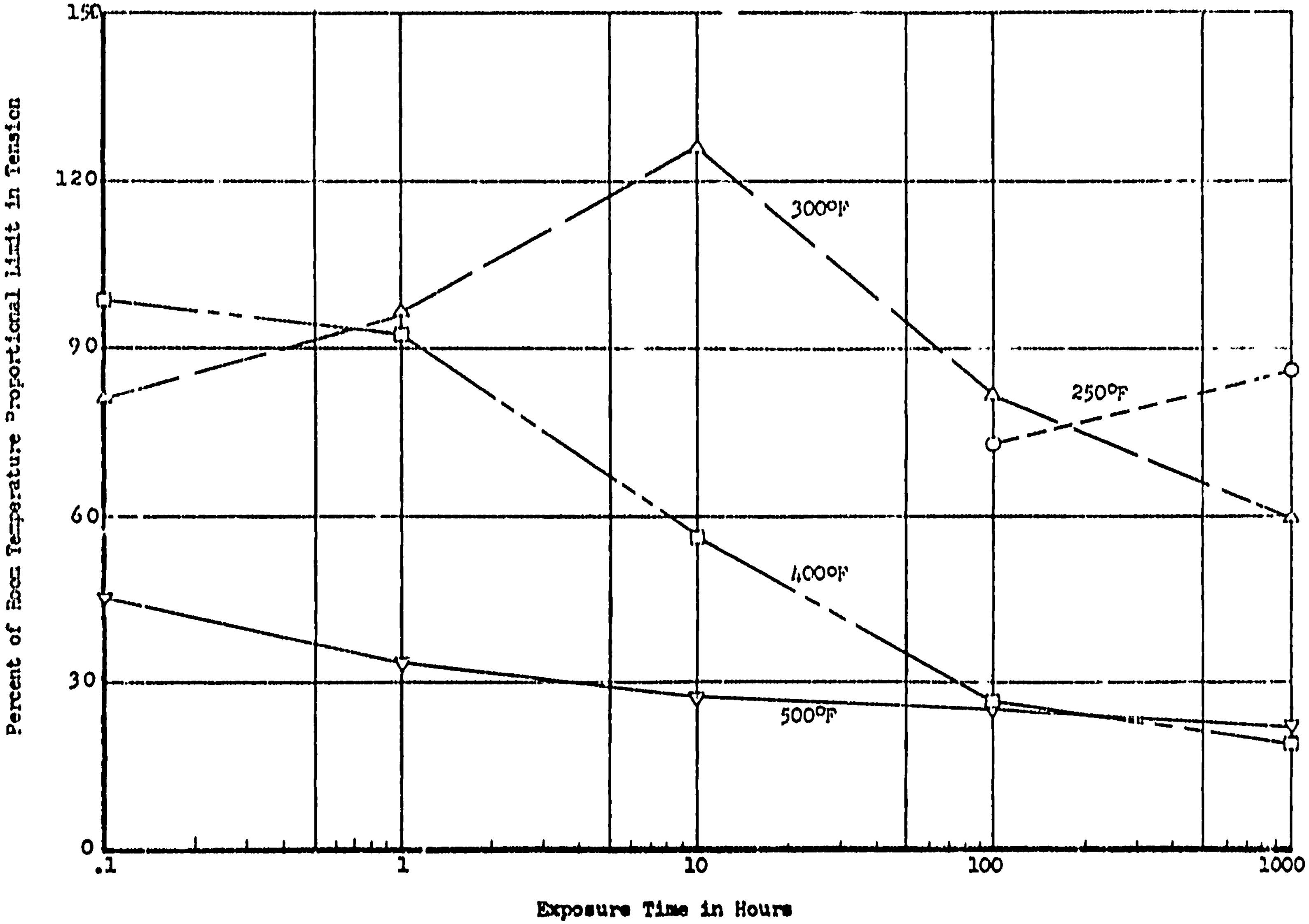

Figure 66. Proportional Limit in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

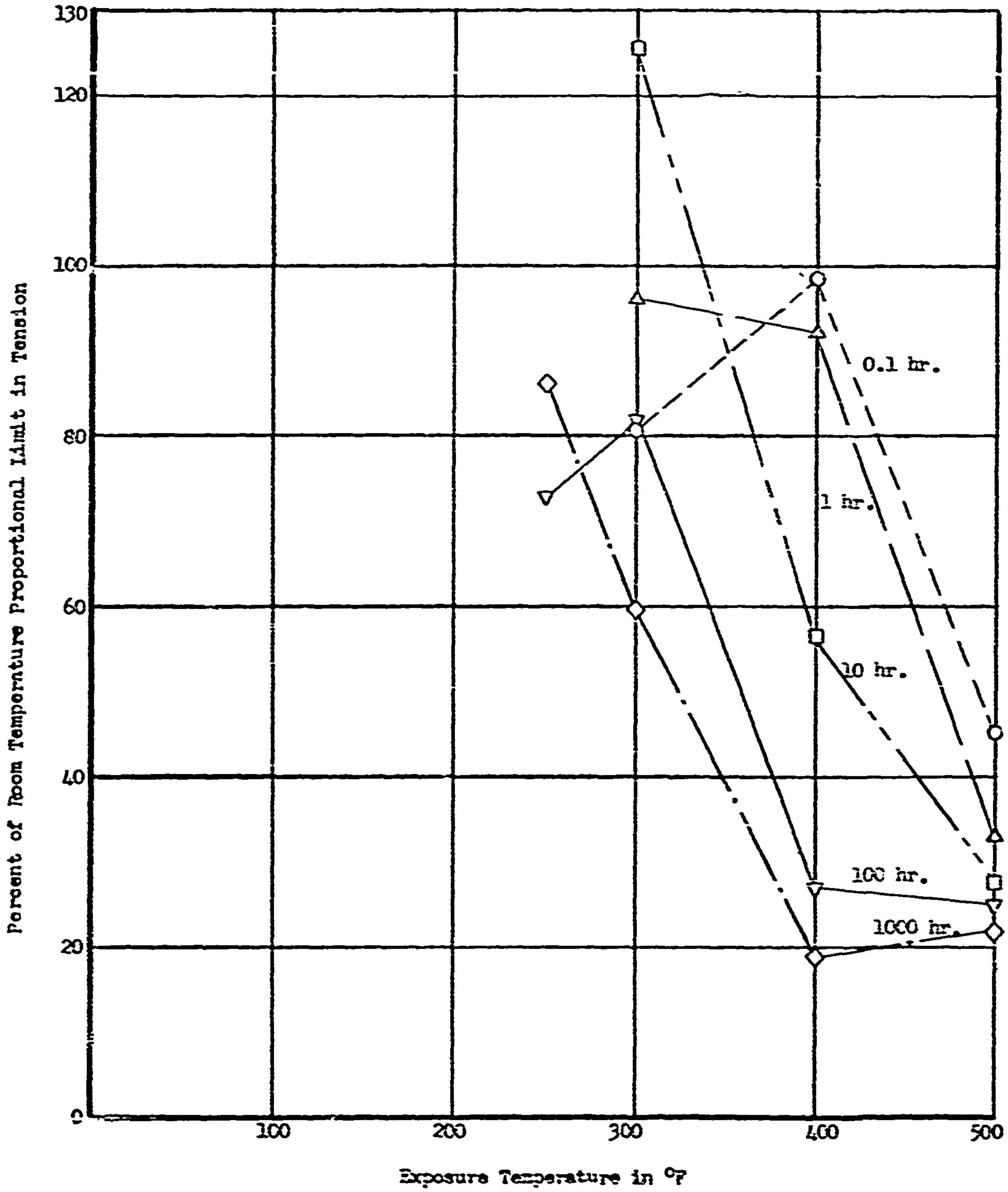

Figure 67. Proportional Limit in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

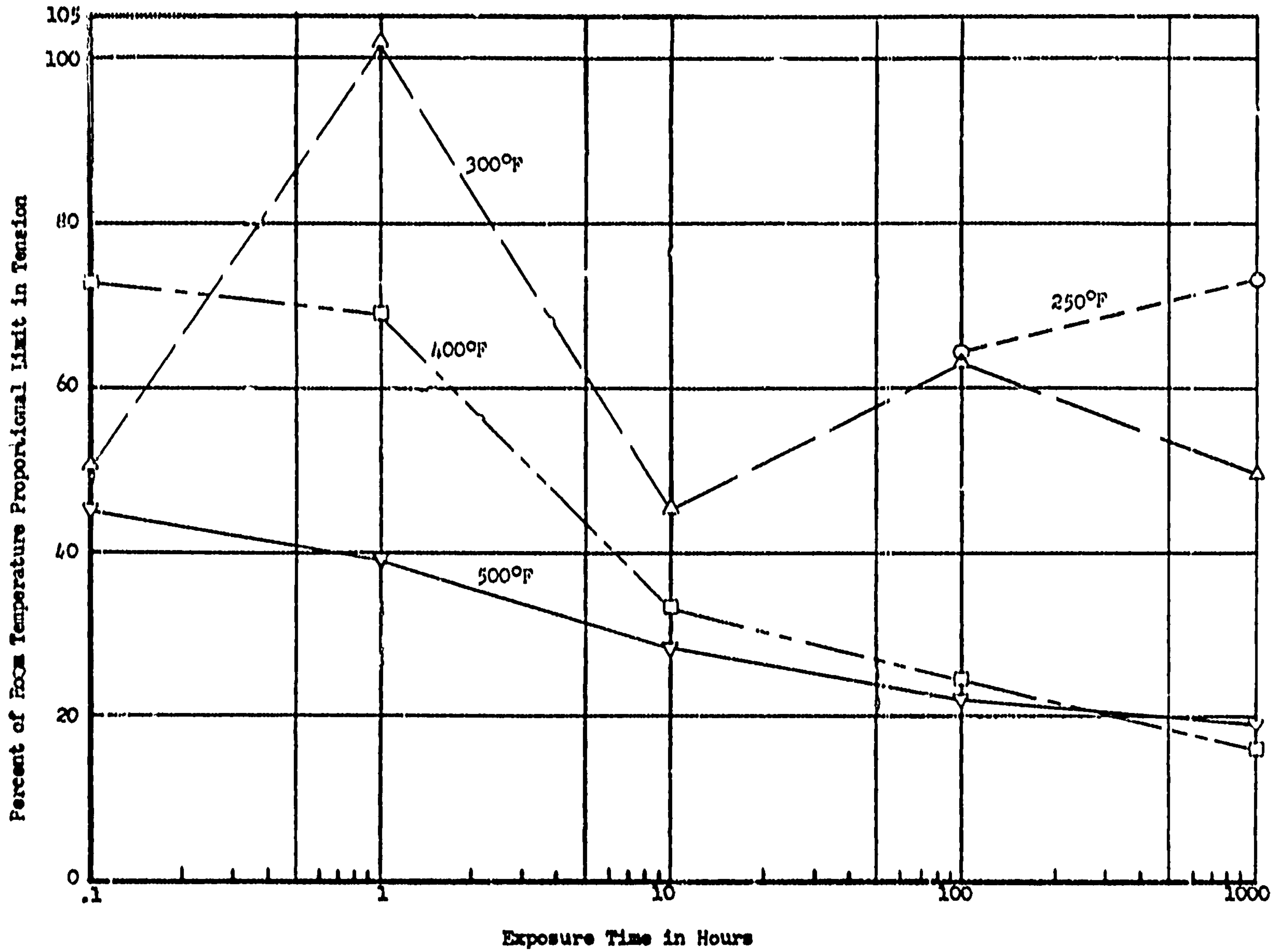

Figure 68. Proportional Limit in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

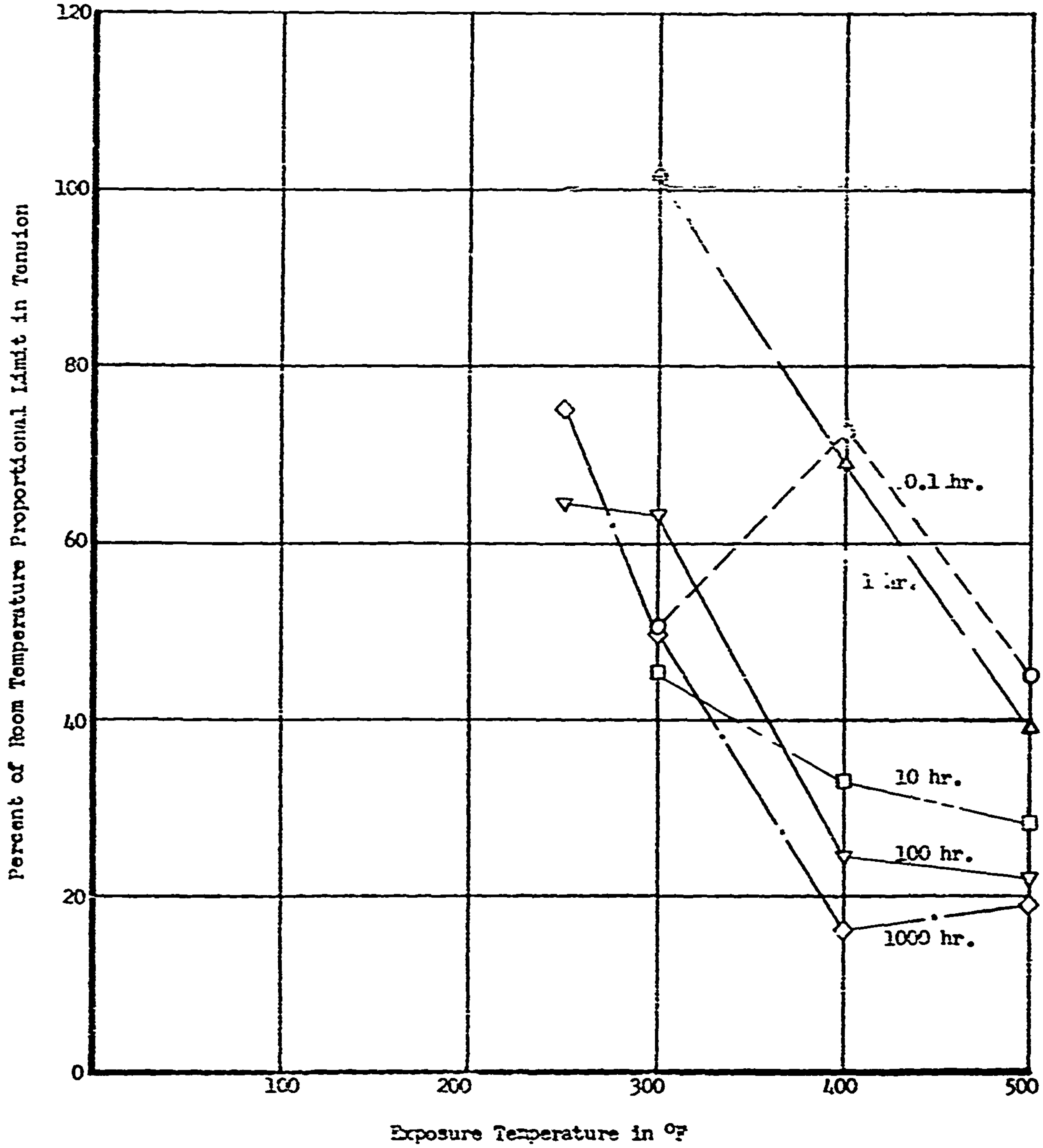

Figure 69. Proportional Limit in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

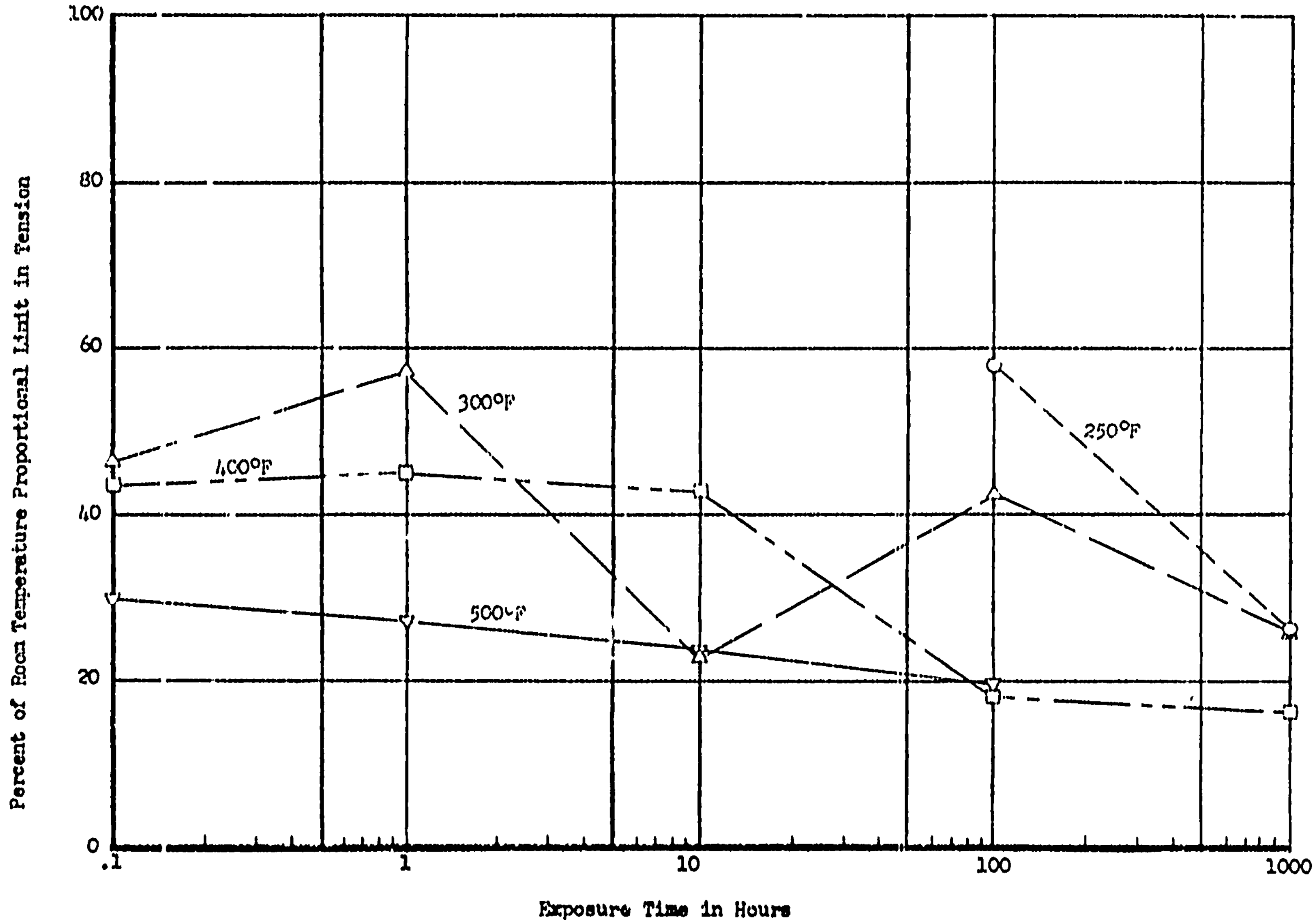

Figure 70. Proportional Limit in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

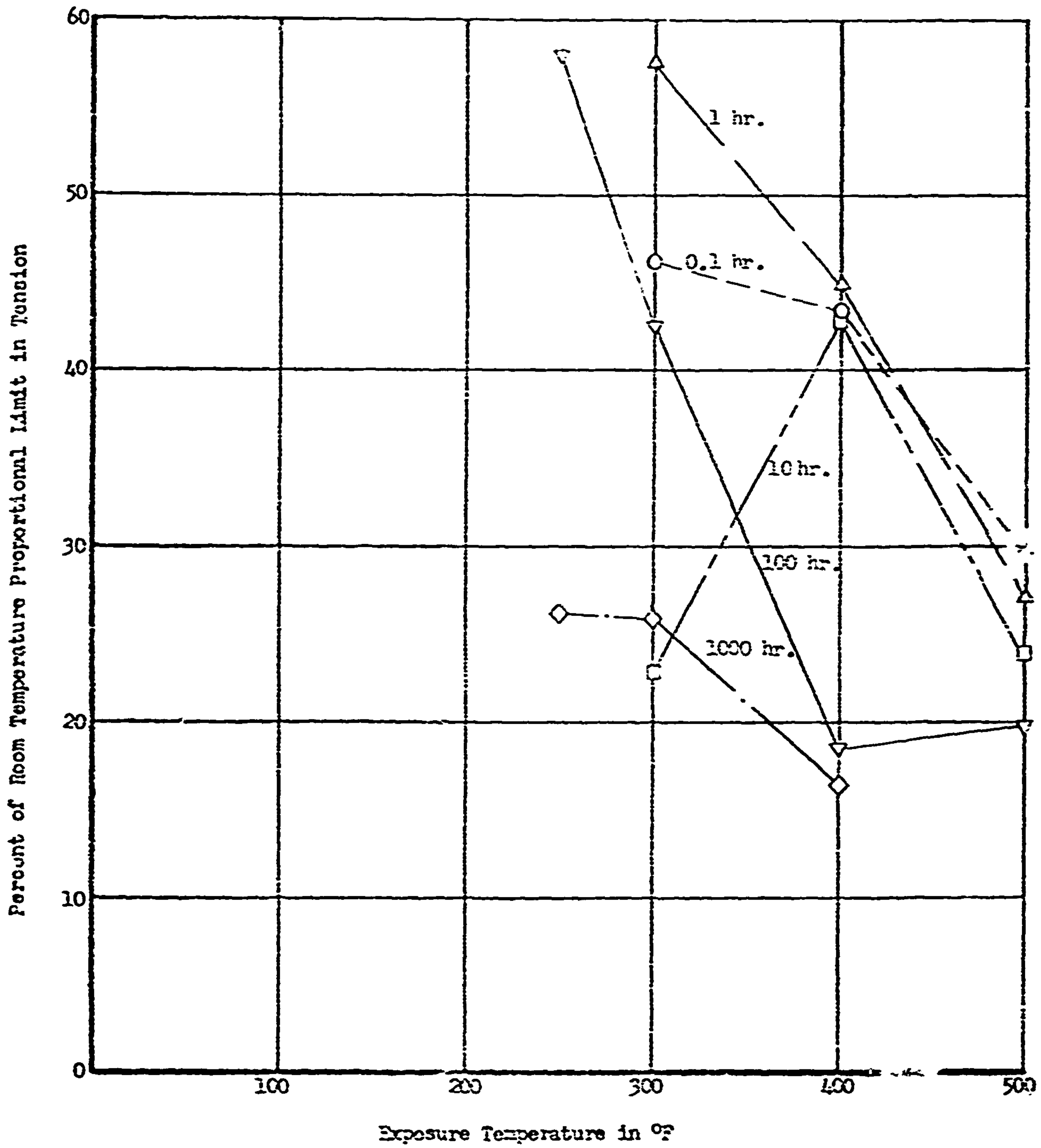

Figure 71. Proportional Limit in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

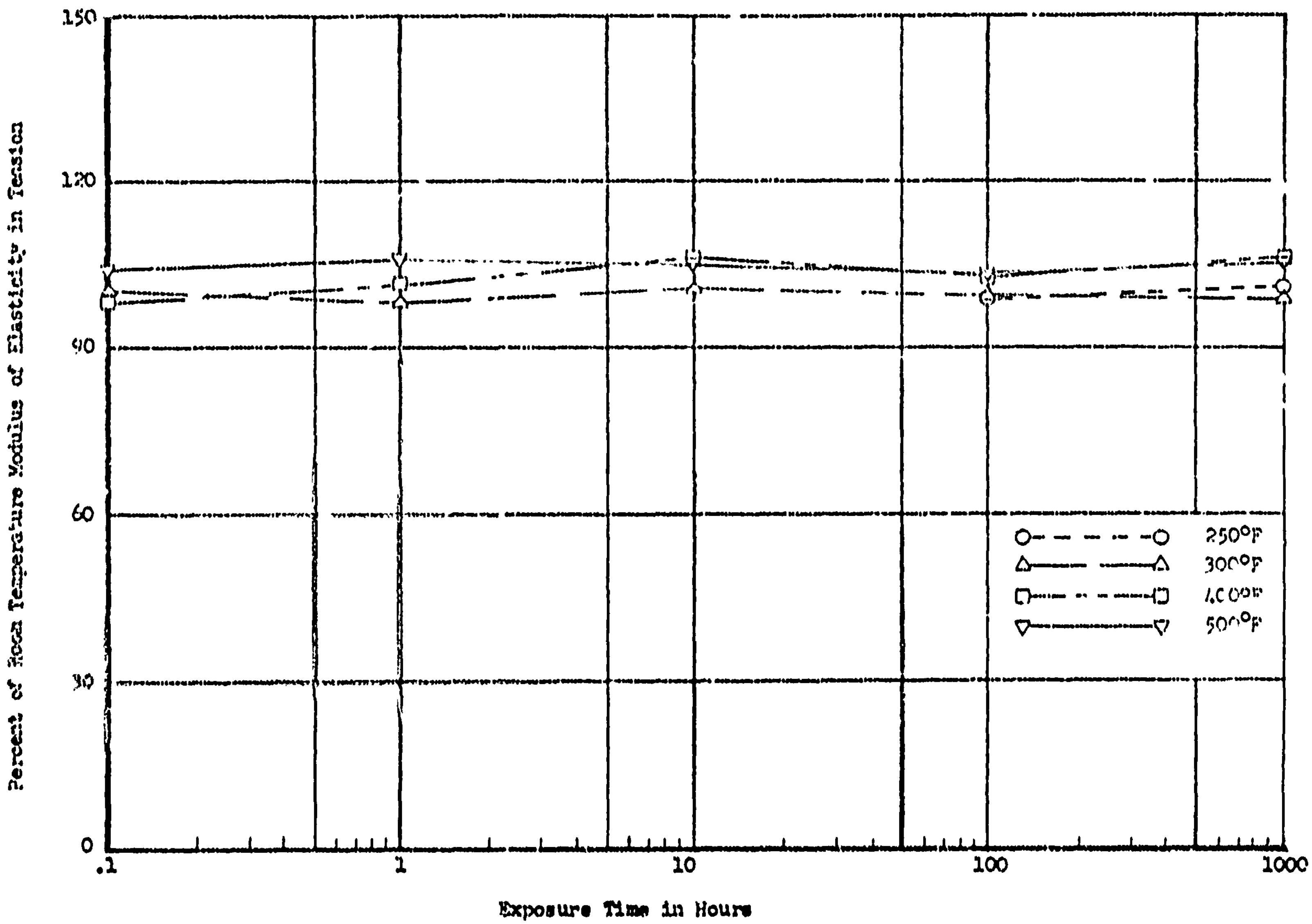

Figure 72. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

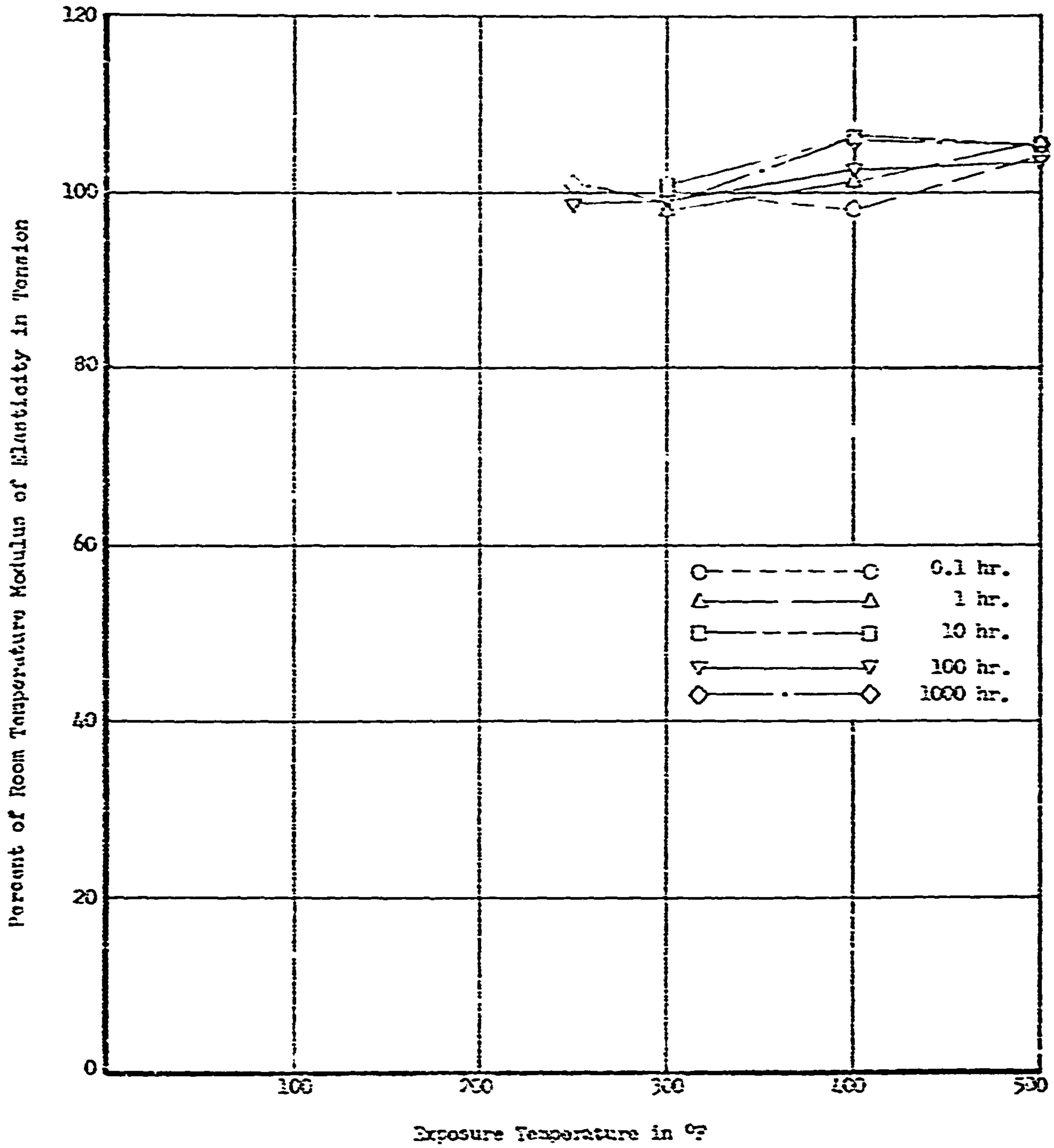

Figure 73. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

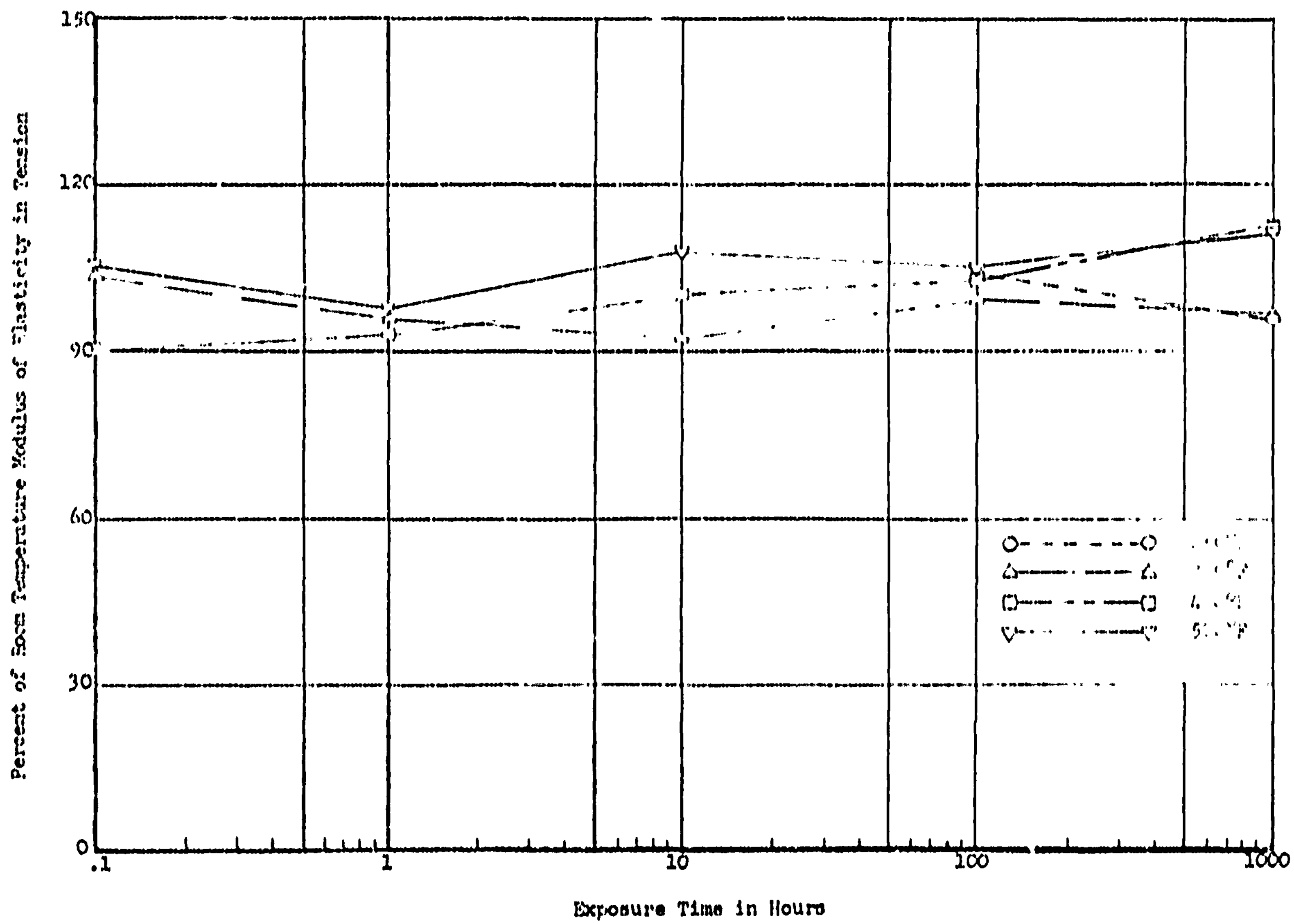

Figure 74. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

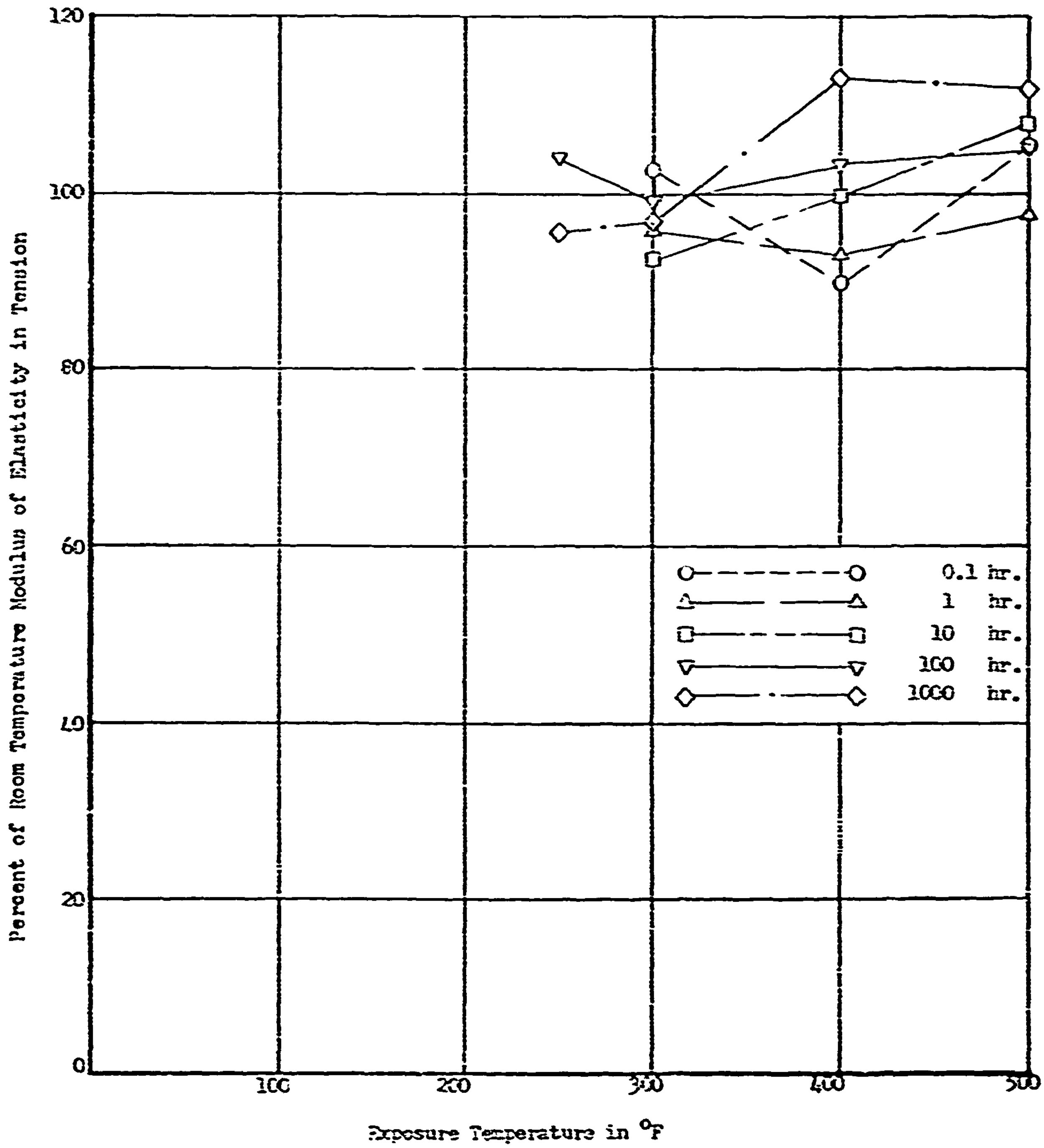

Figure 75. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

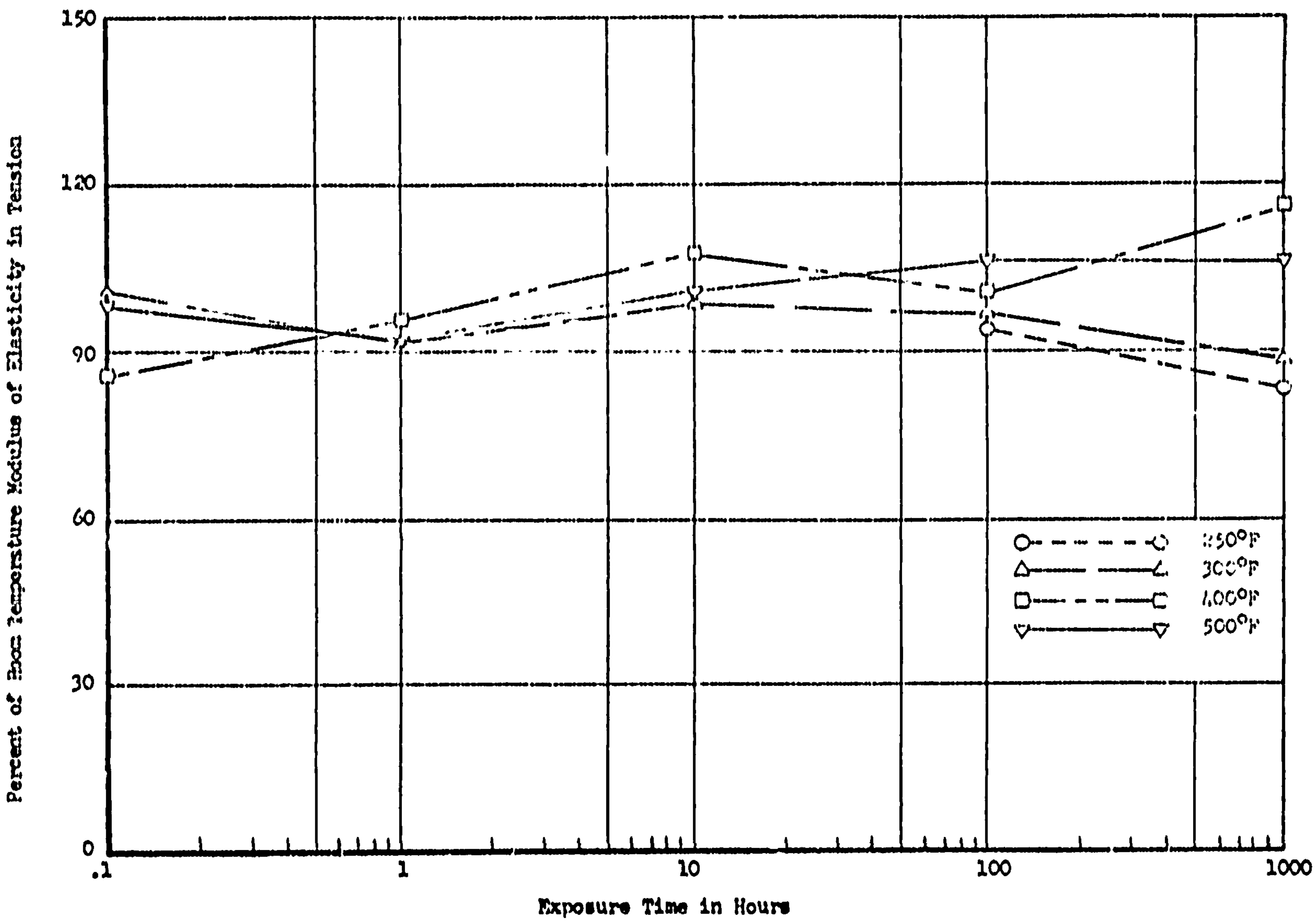

Figure 76. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

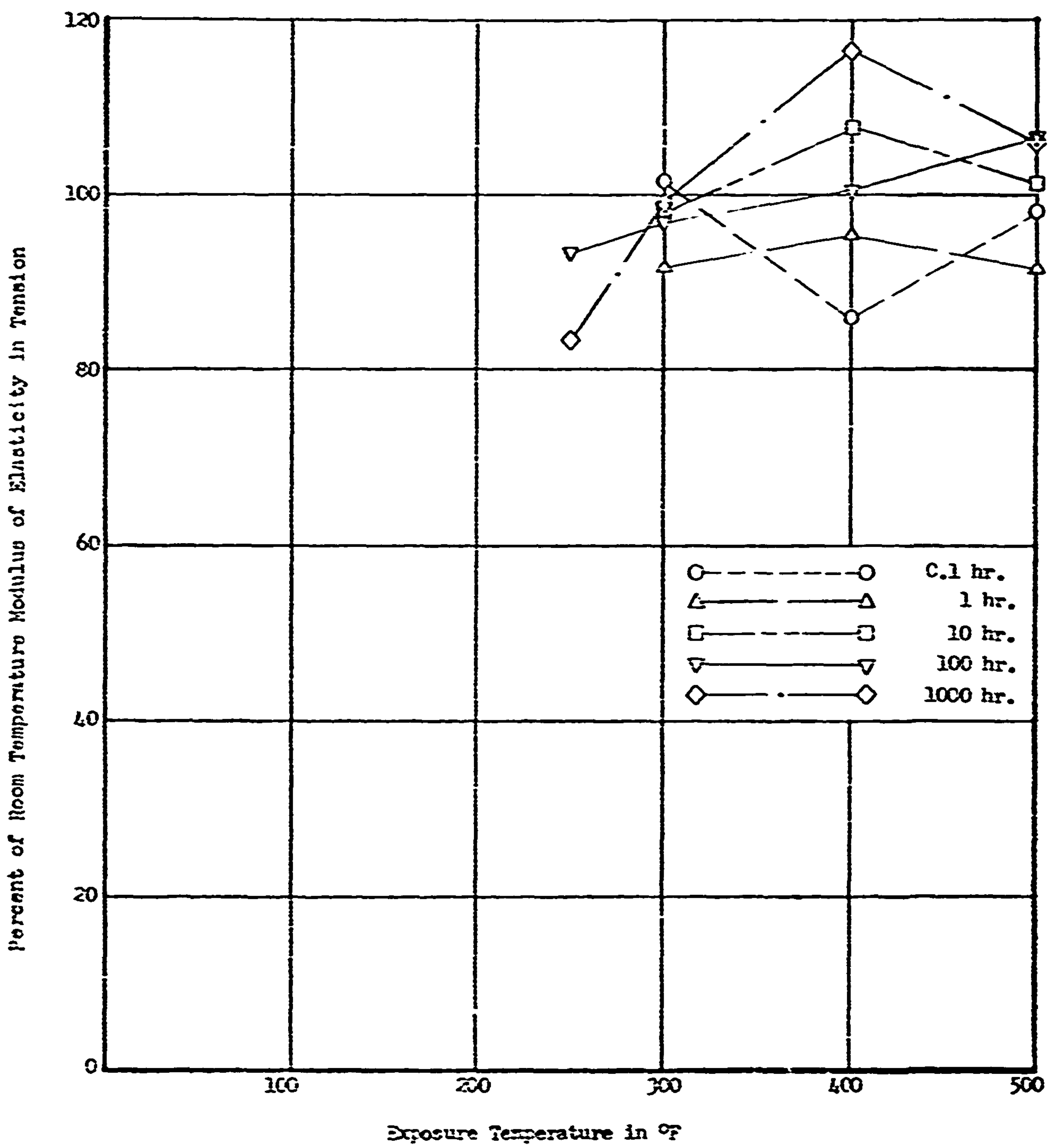

Figure 77. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

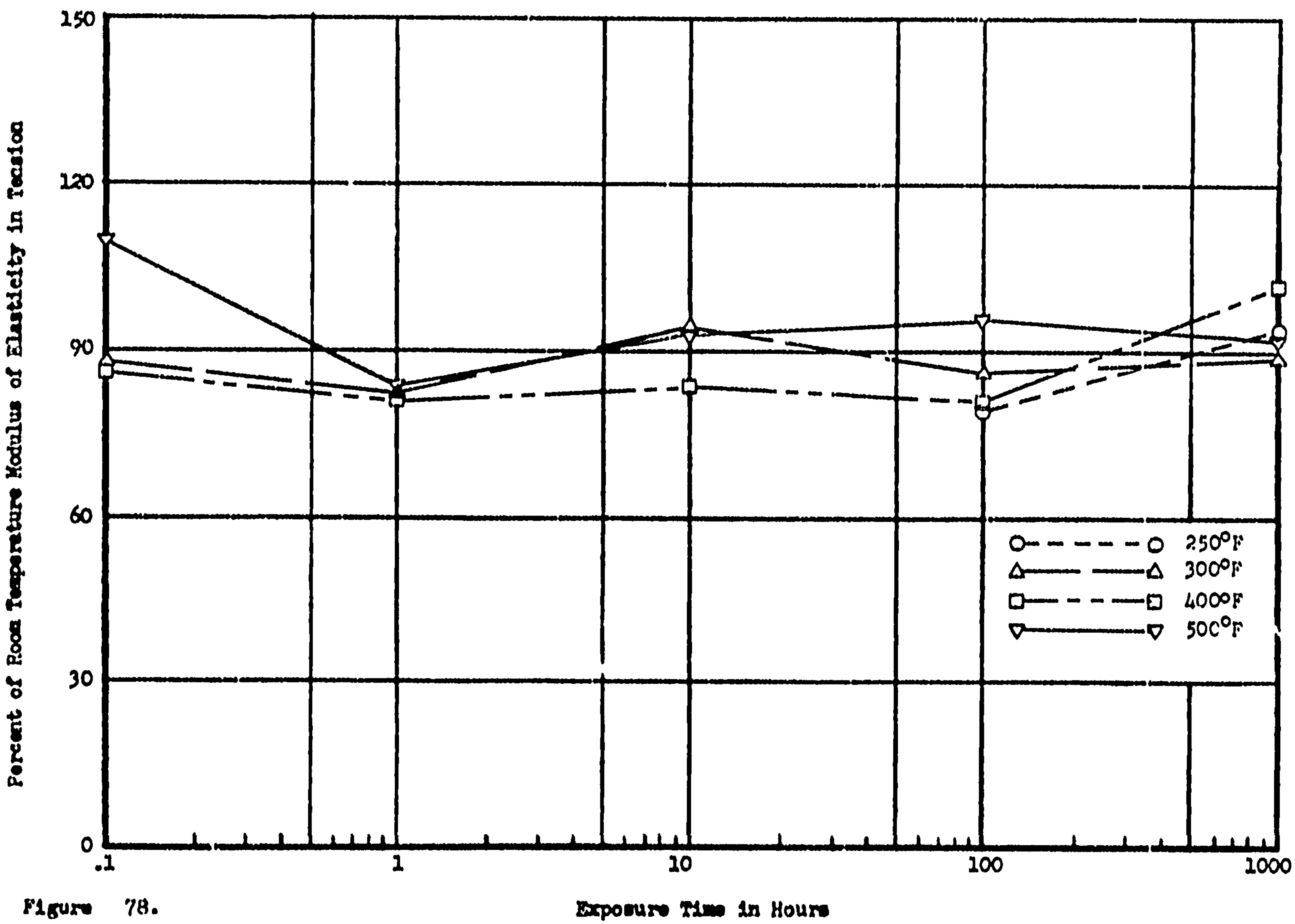

Figure 78.

Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

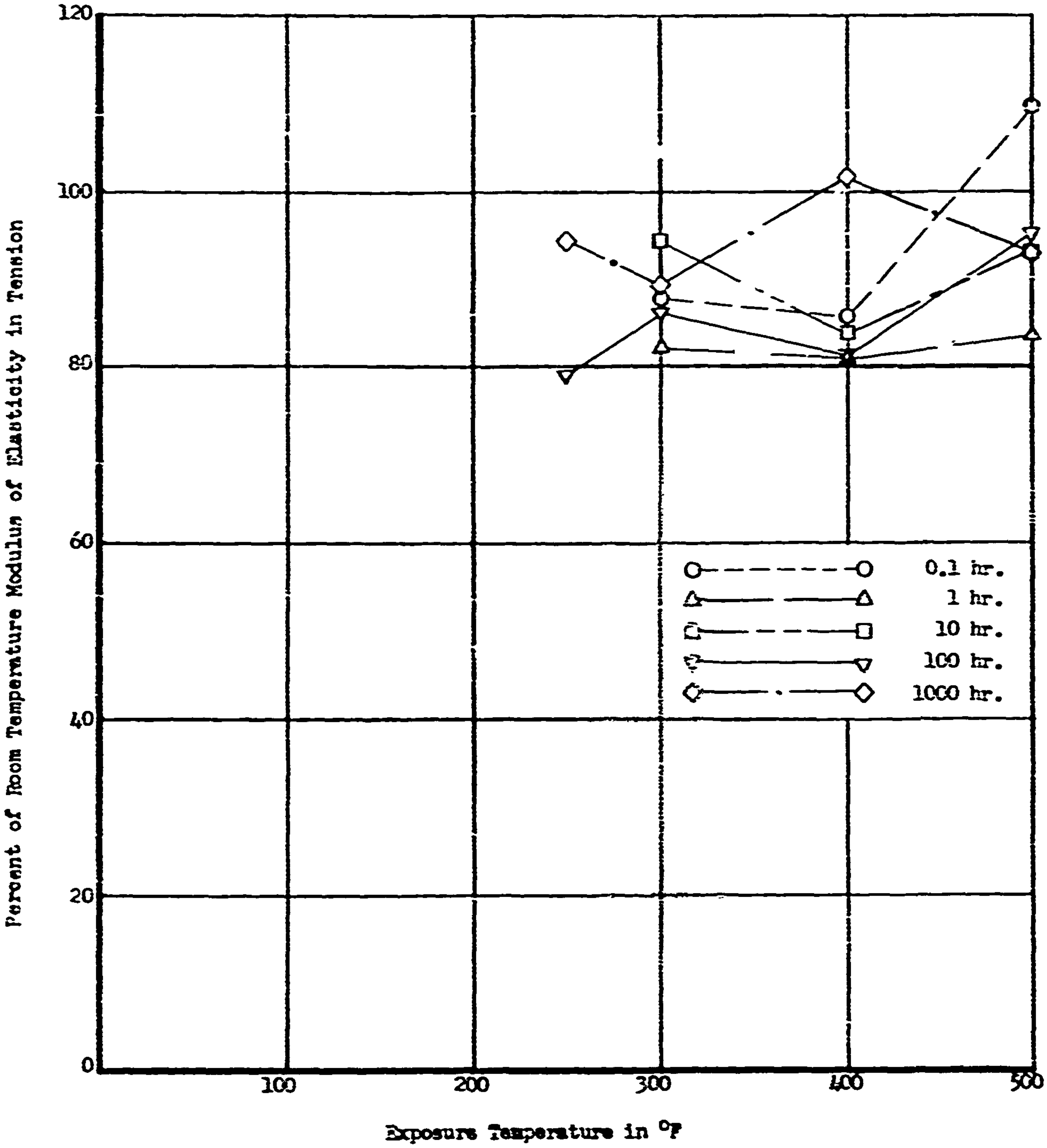

Figure 79. Modulus of Elasticity in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

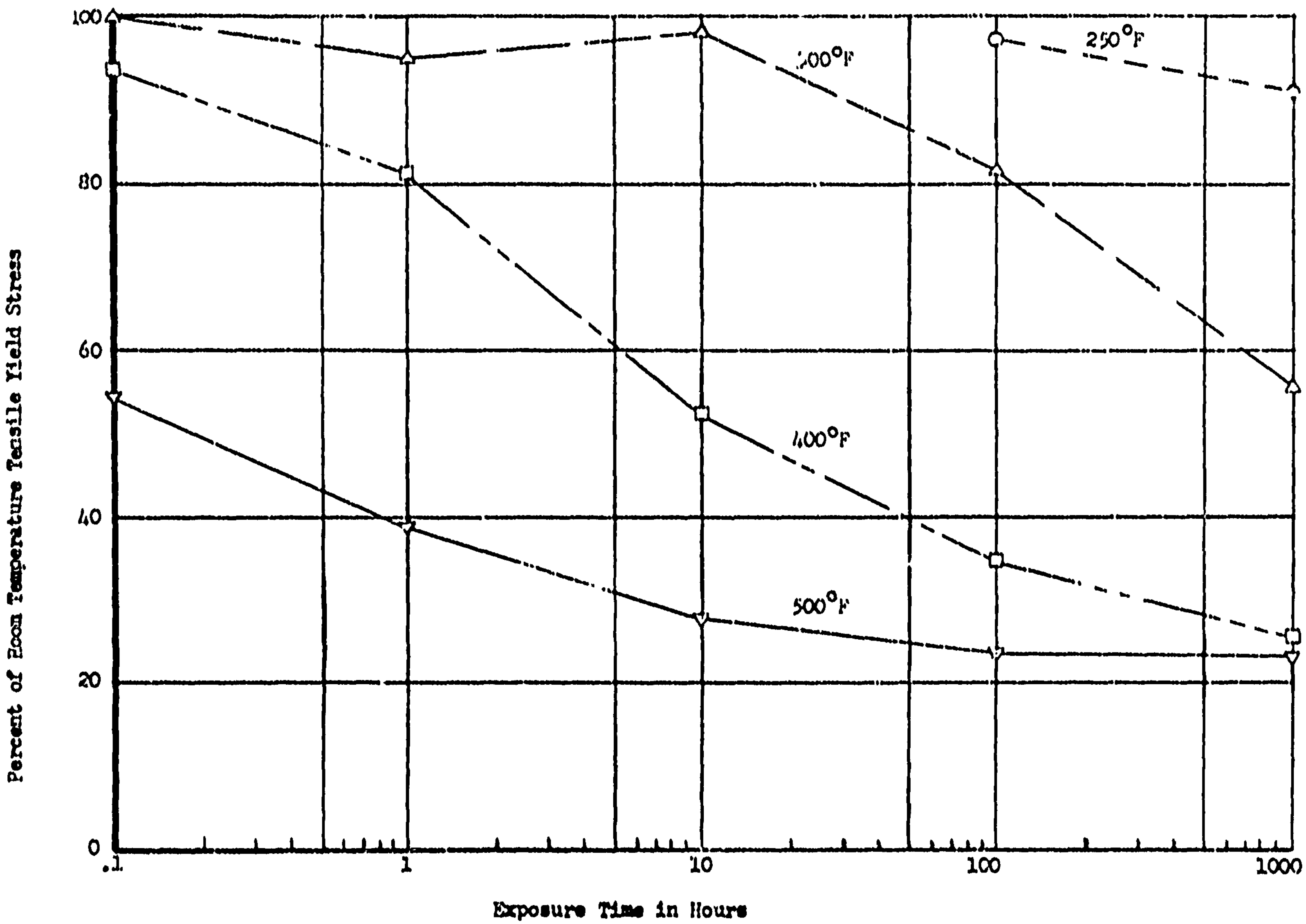

Figure 80. Tensile Yield Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

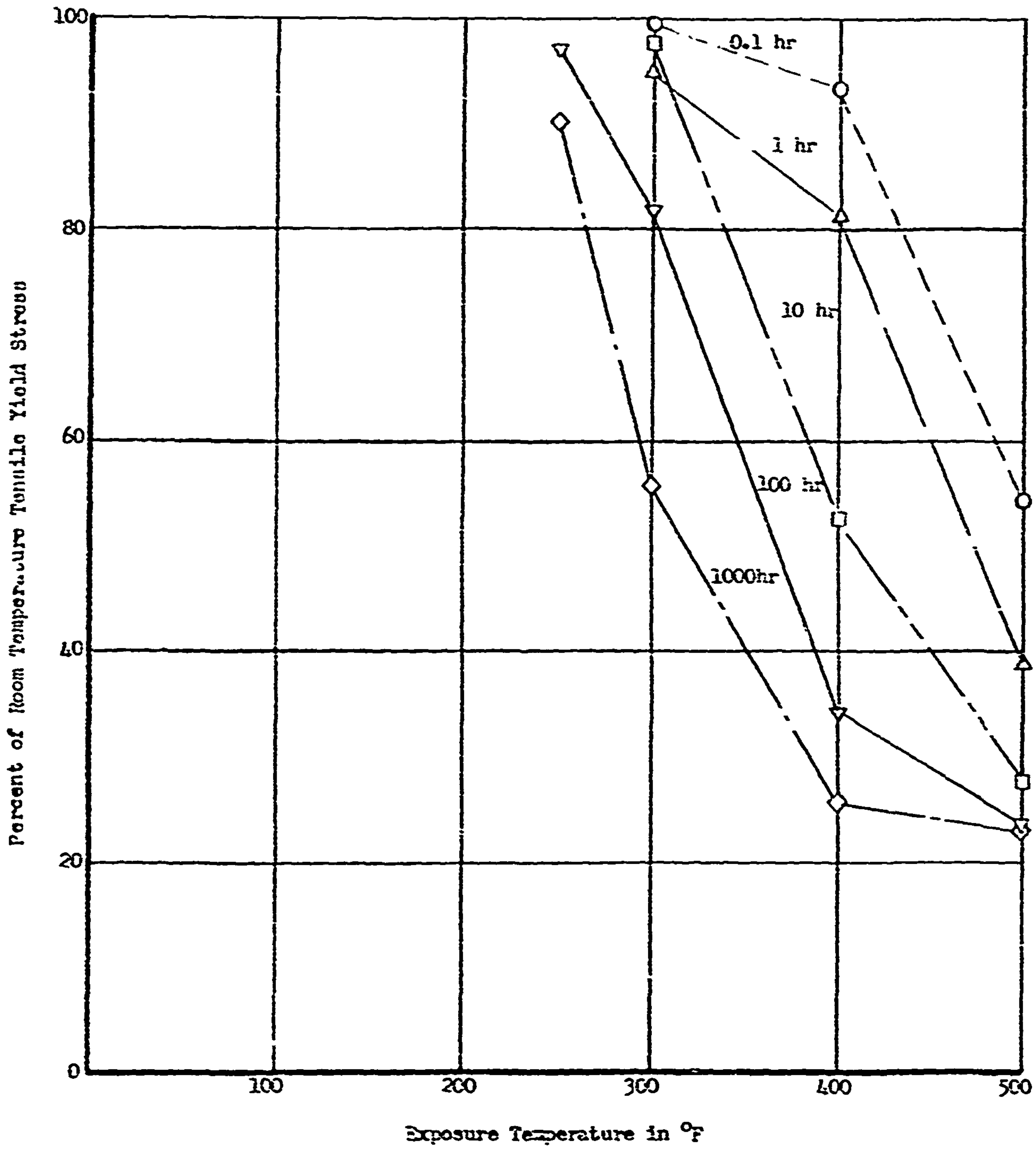

Figure 81. Tensile Yield Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

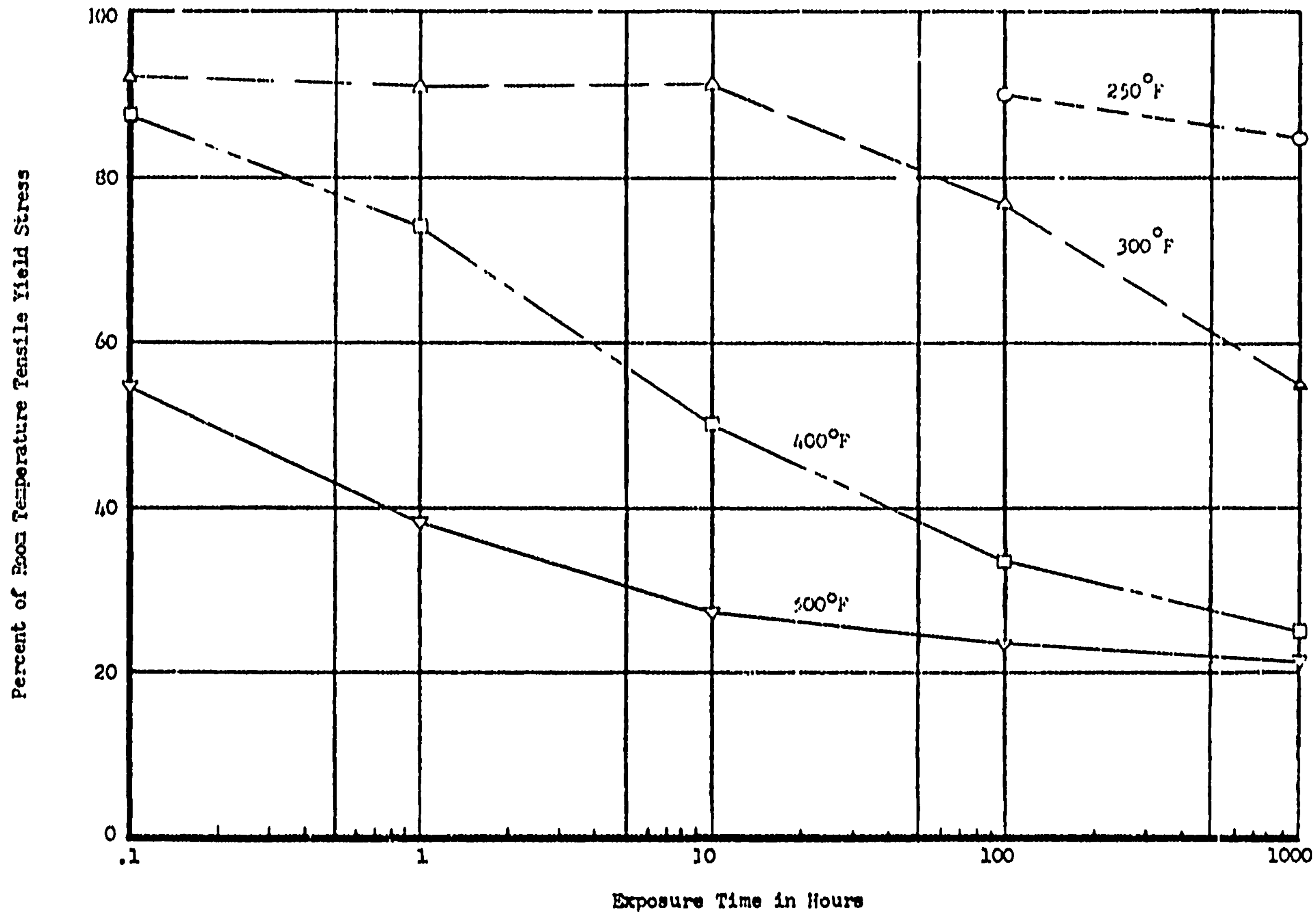

Figure 82. Tensile Yield Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

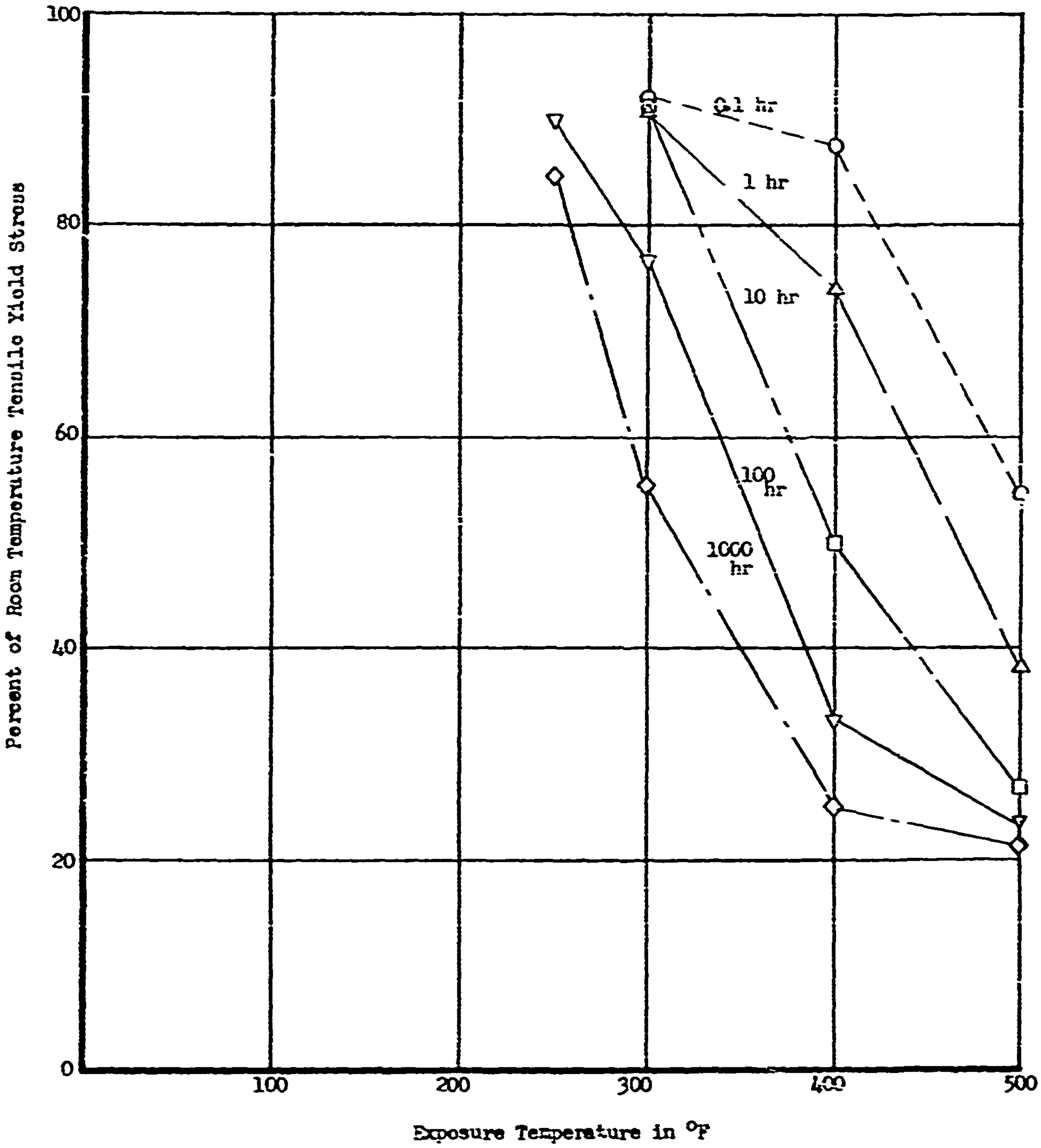

Figure 83. Tensile Yield Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

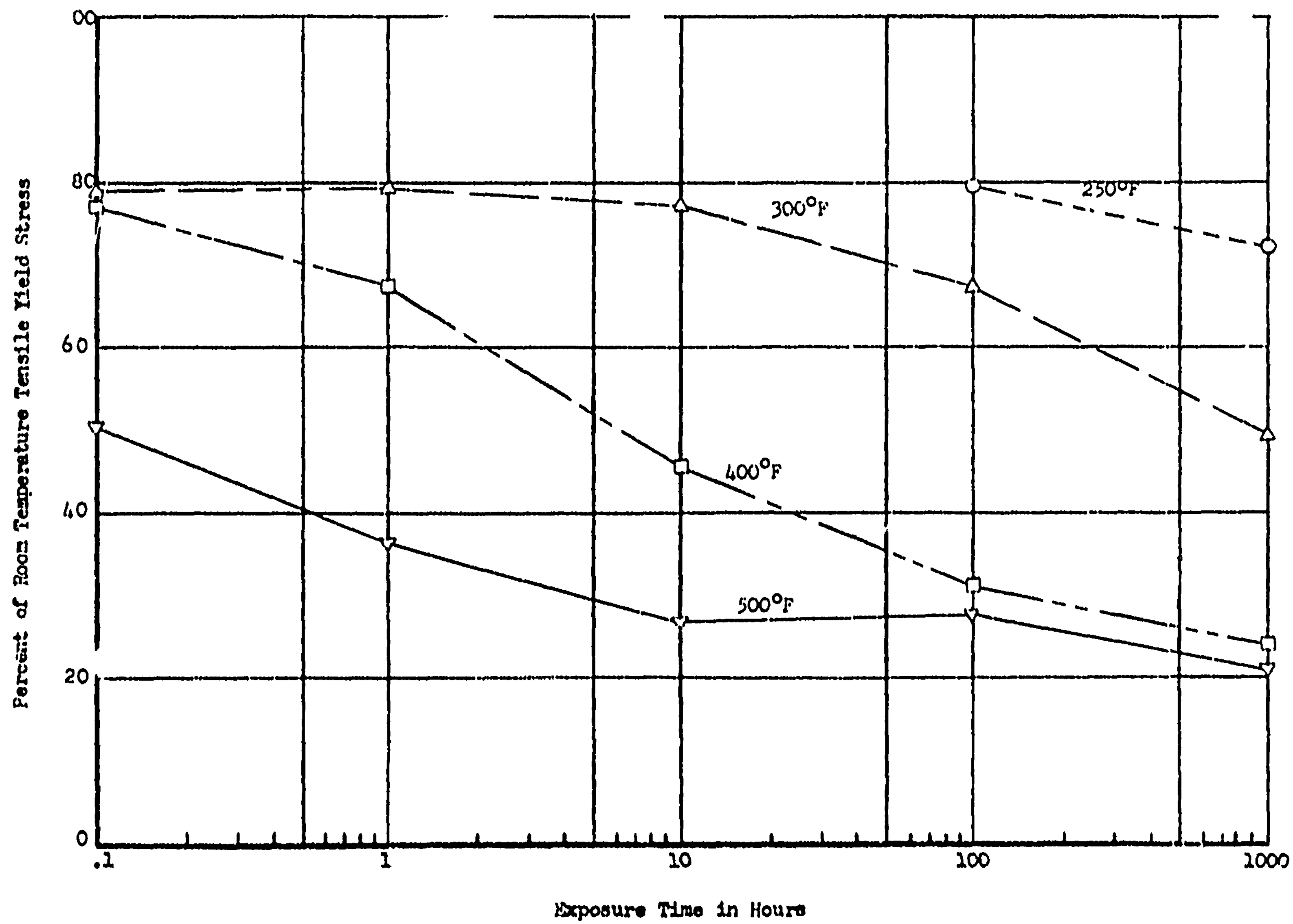

Figure 84. Tensile Yield Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

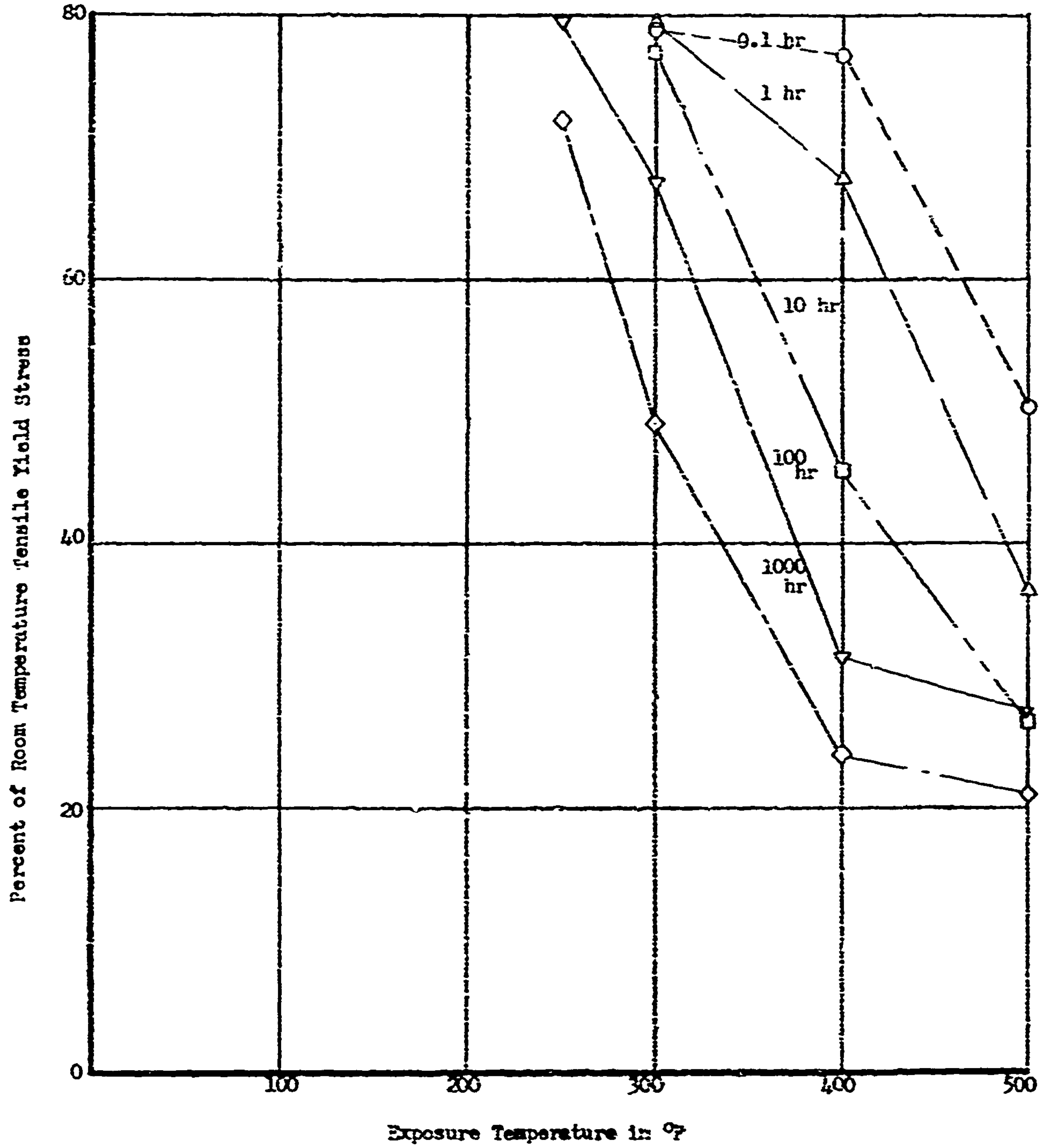

Figure 85. Tensile Yield Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

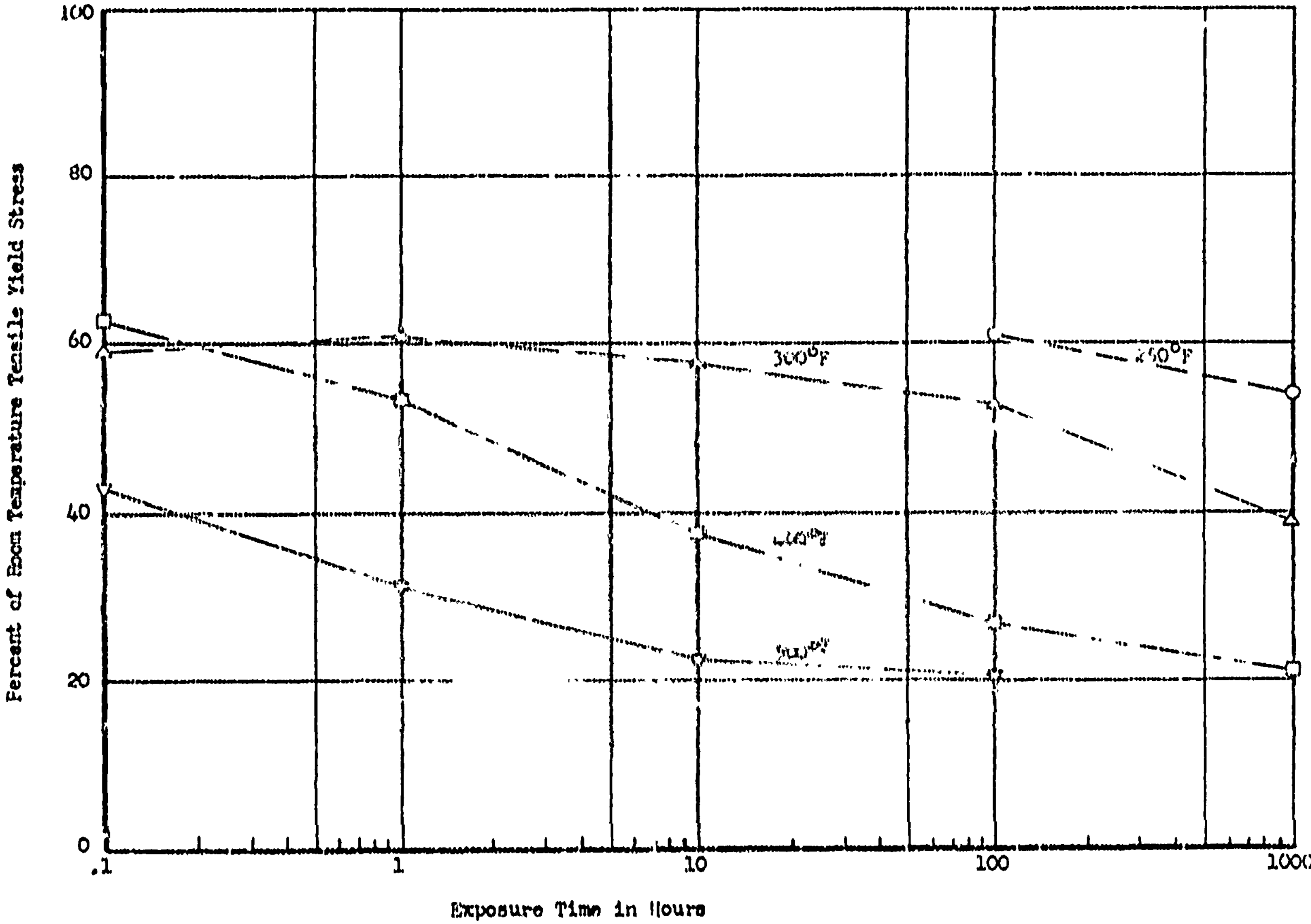

Figure 86. Tensile Yield Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

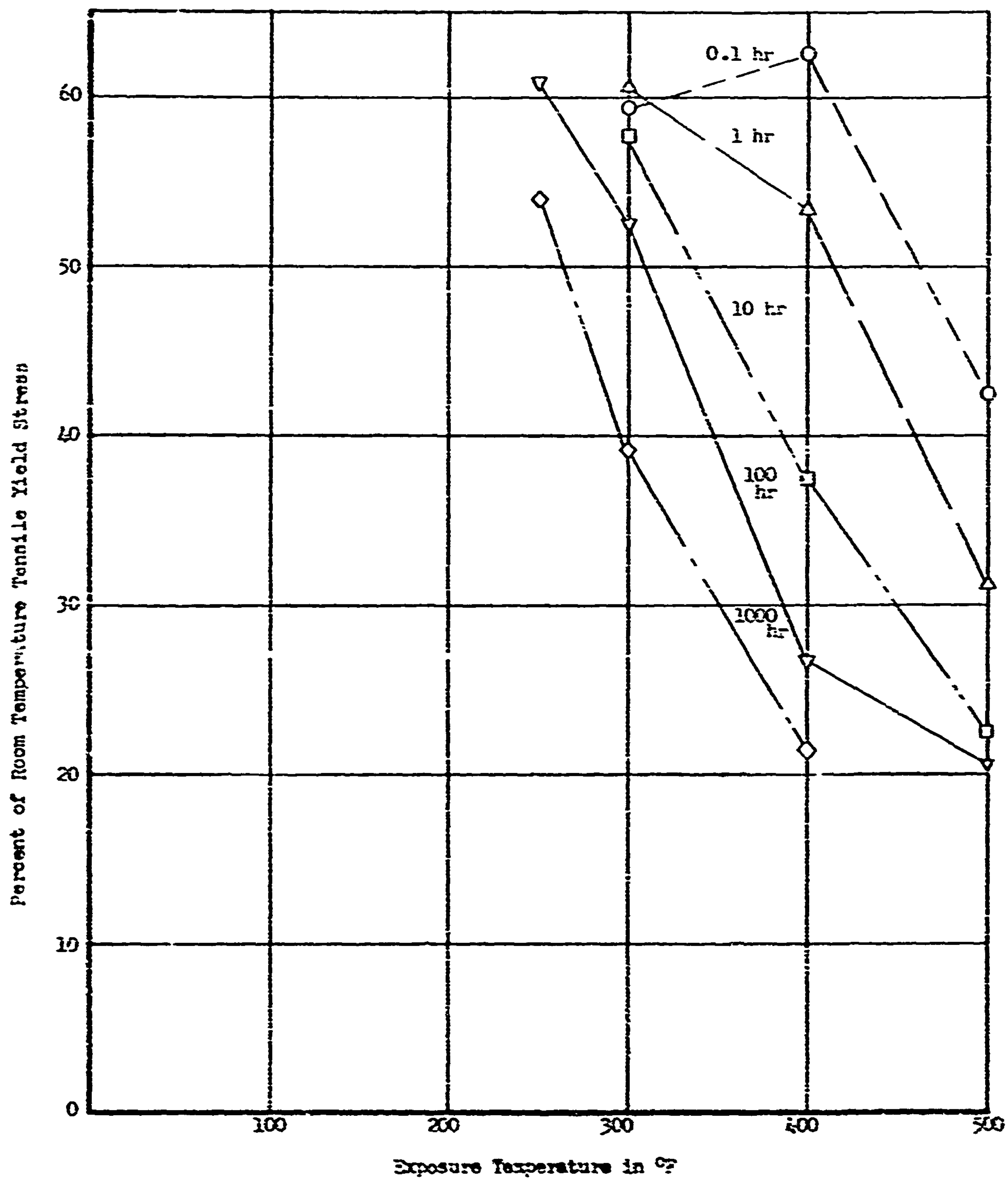

Figure 87. Tensile Yield Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

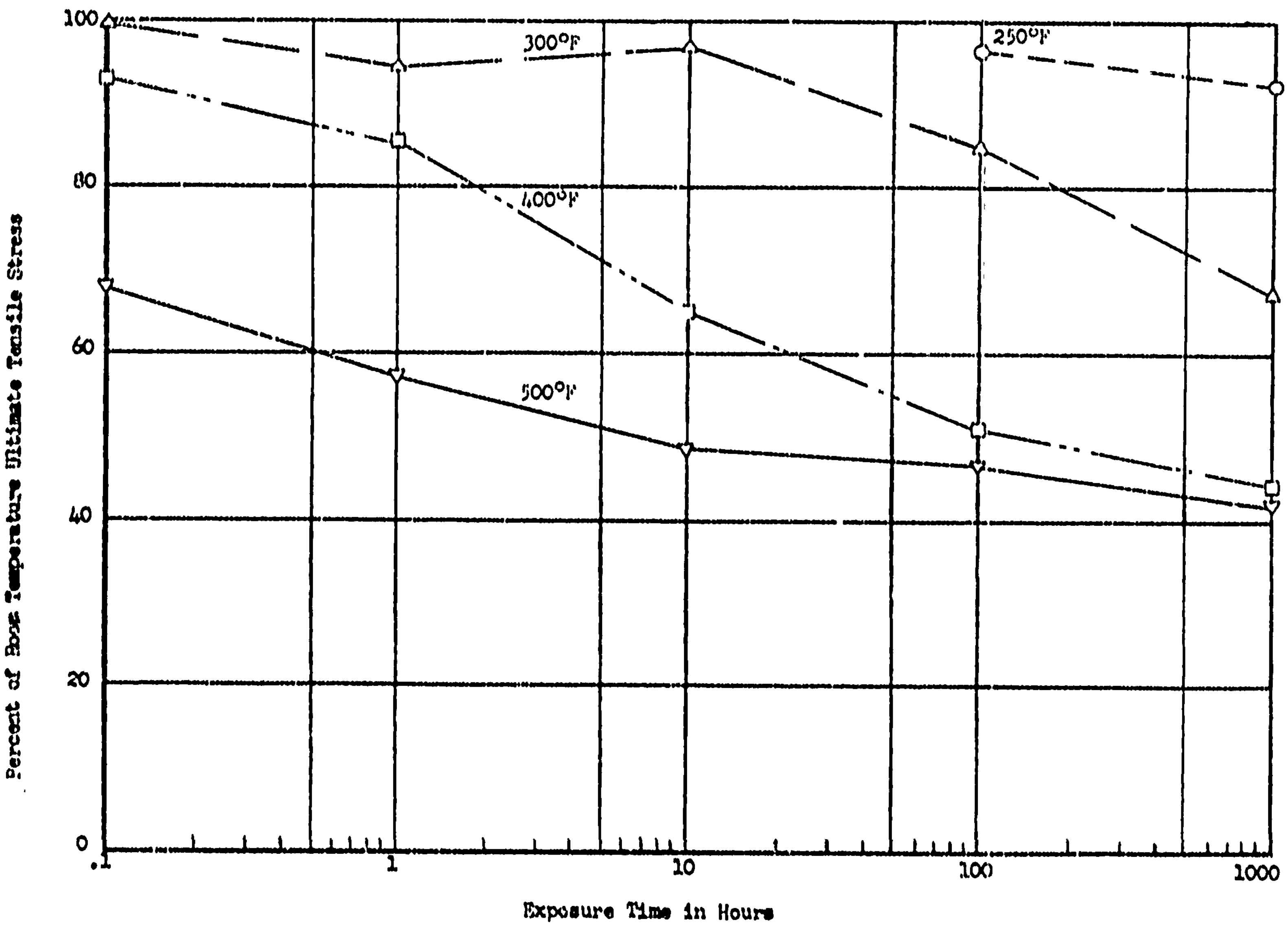

Figure 88. Ultimate Tensile Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

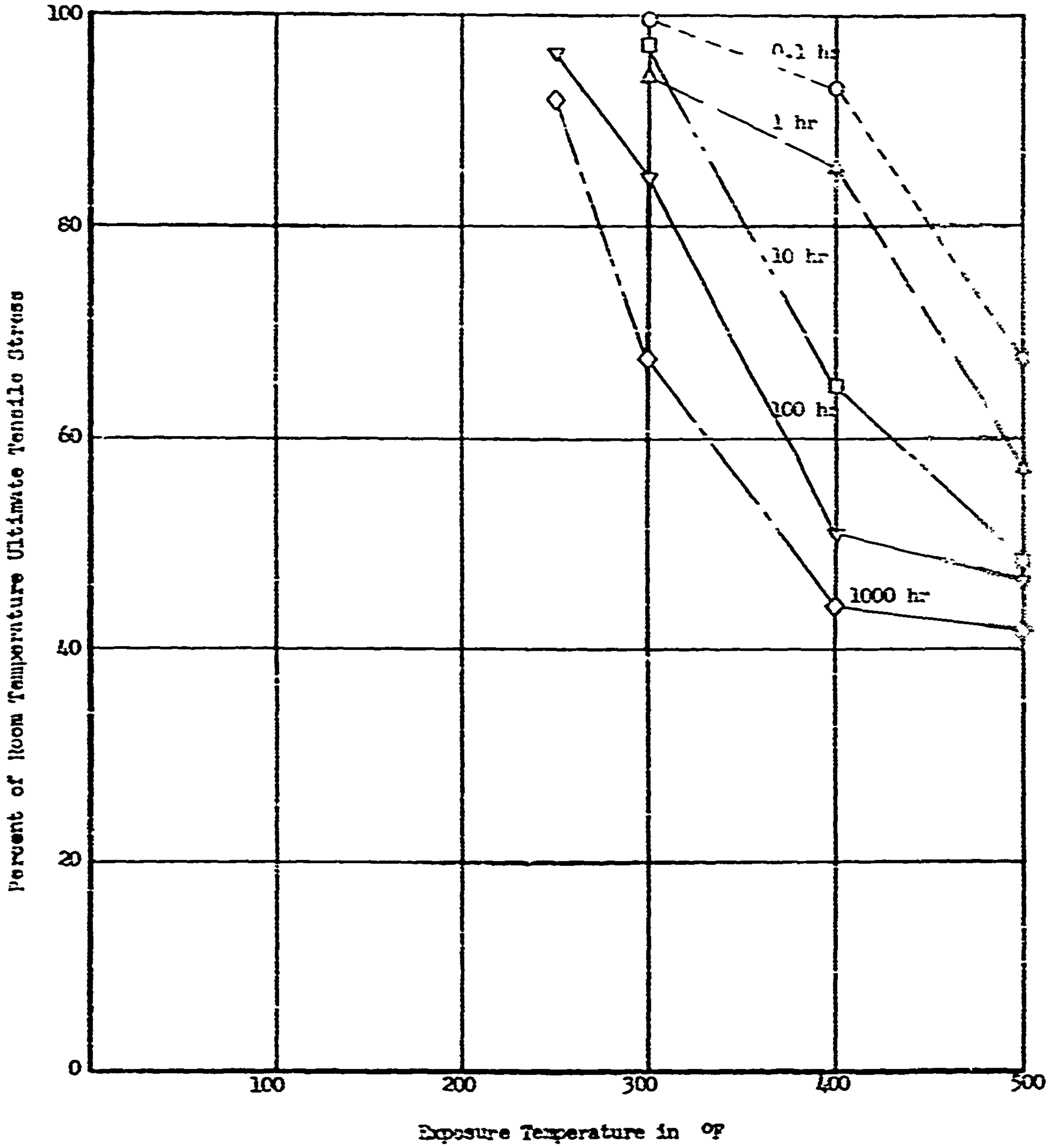

Figure 89. Ultimate Tensile Stress of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

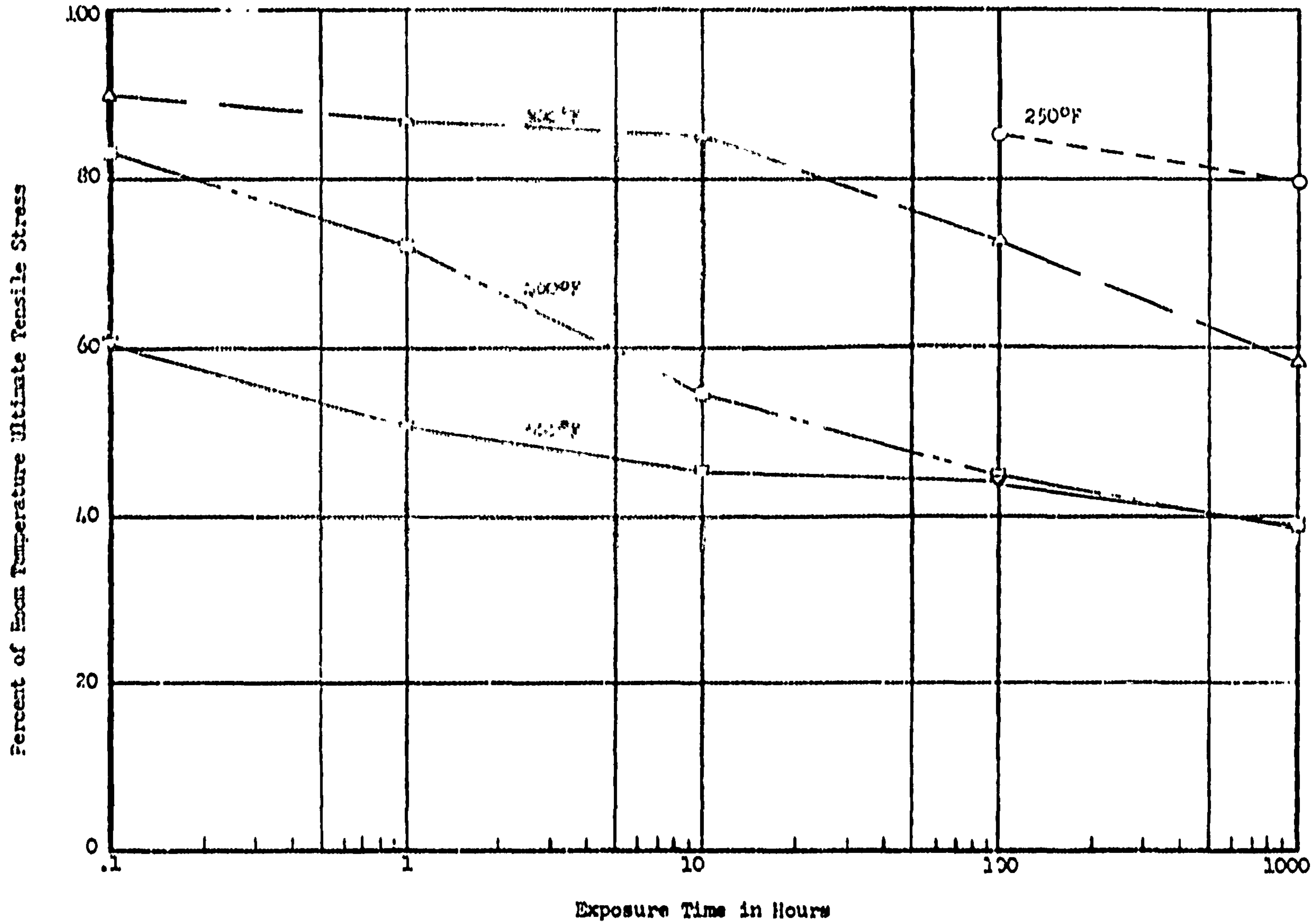

Figure 90. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

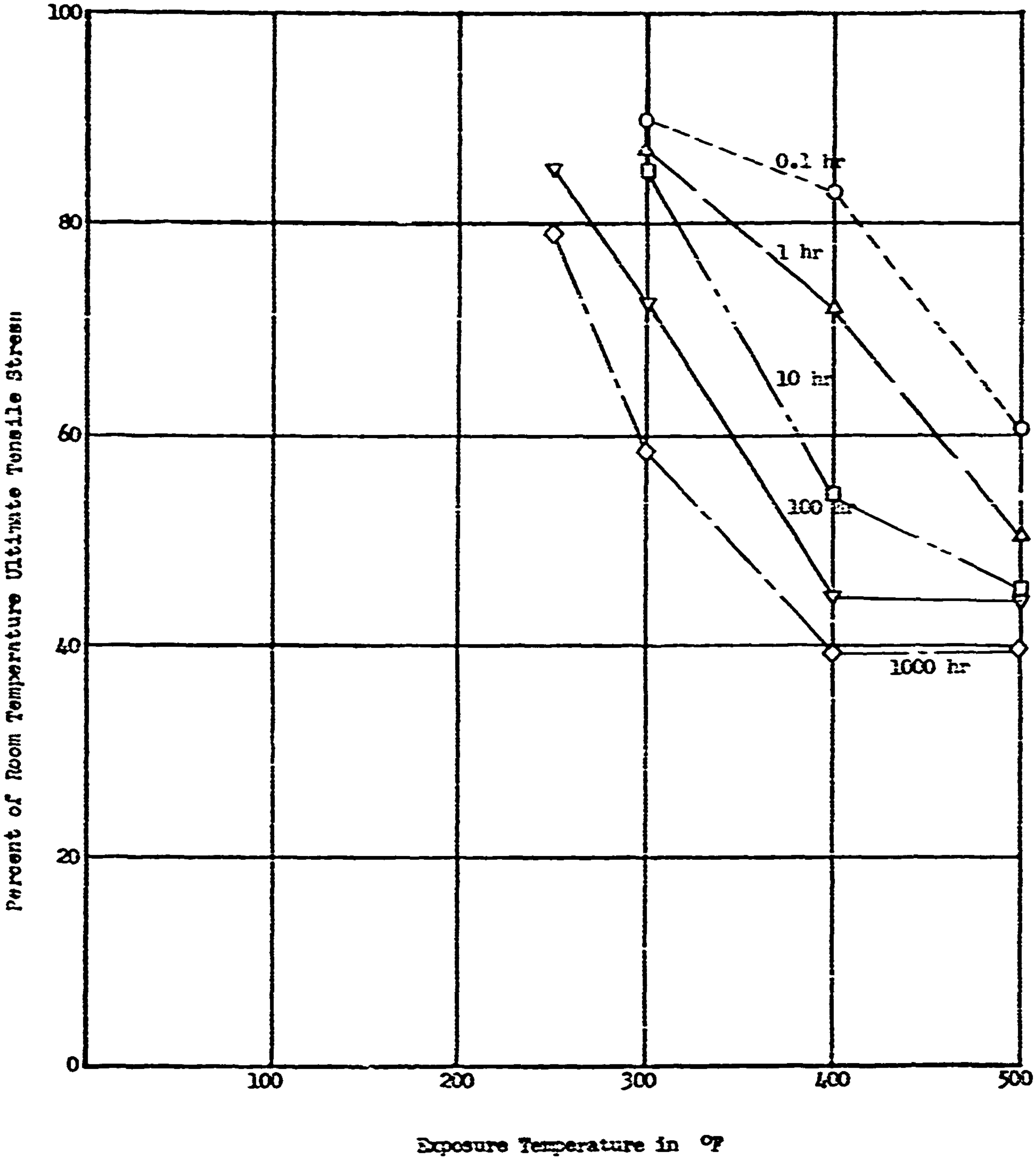

Figure 91. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

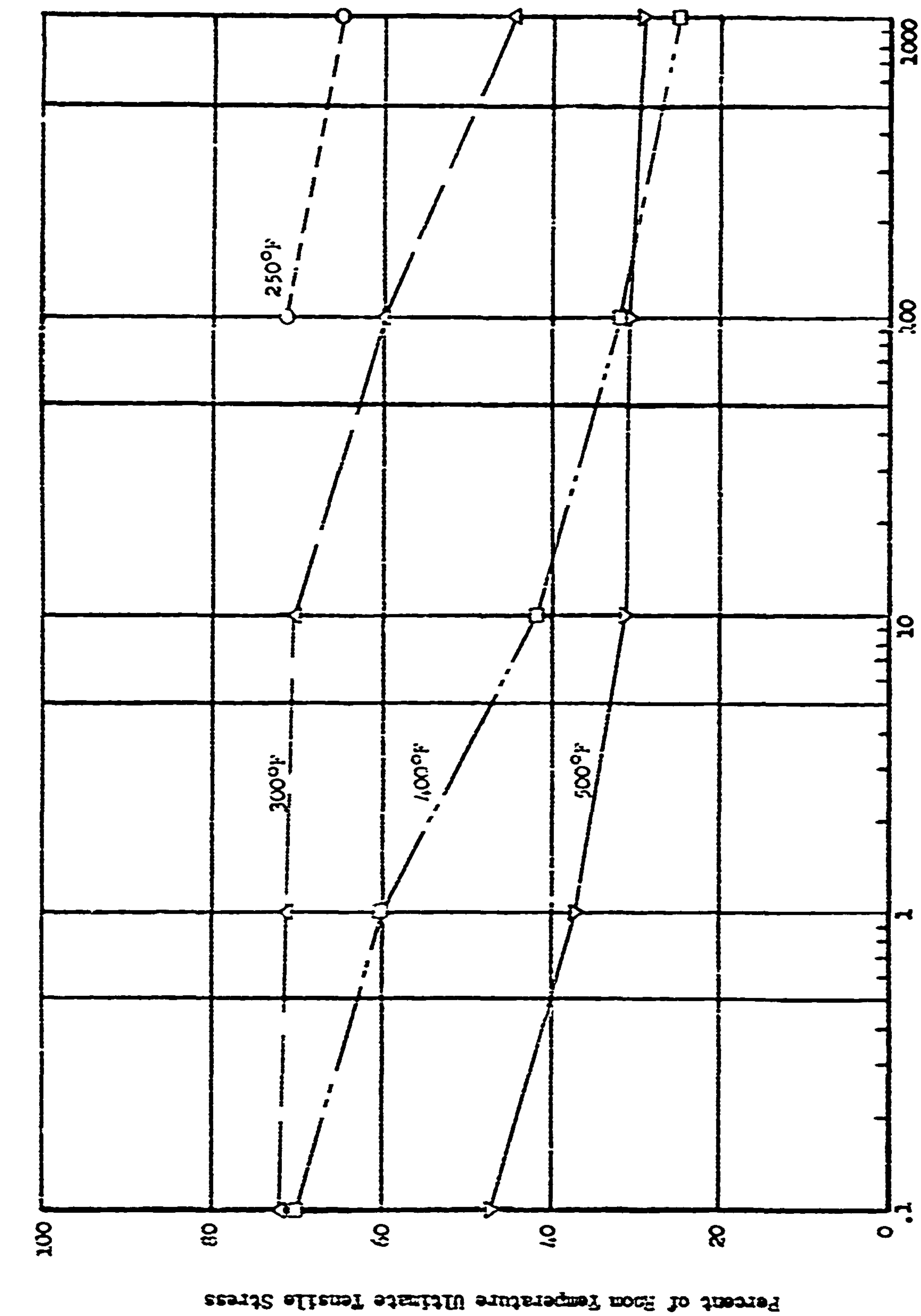

Figure 92. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

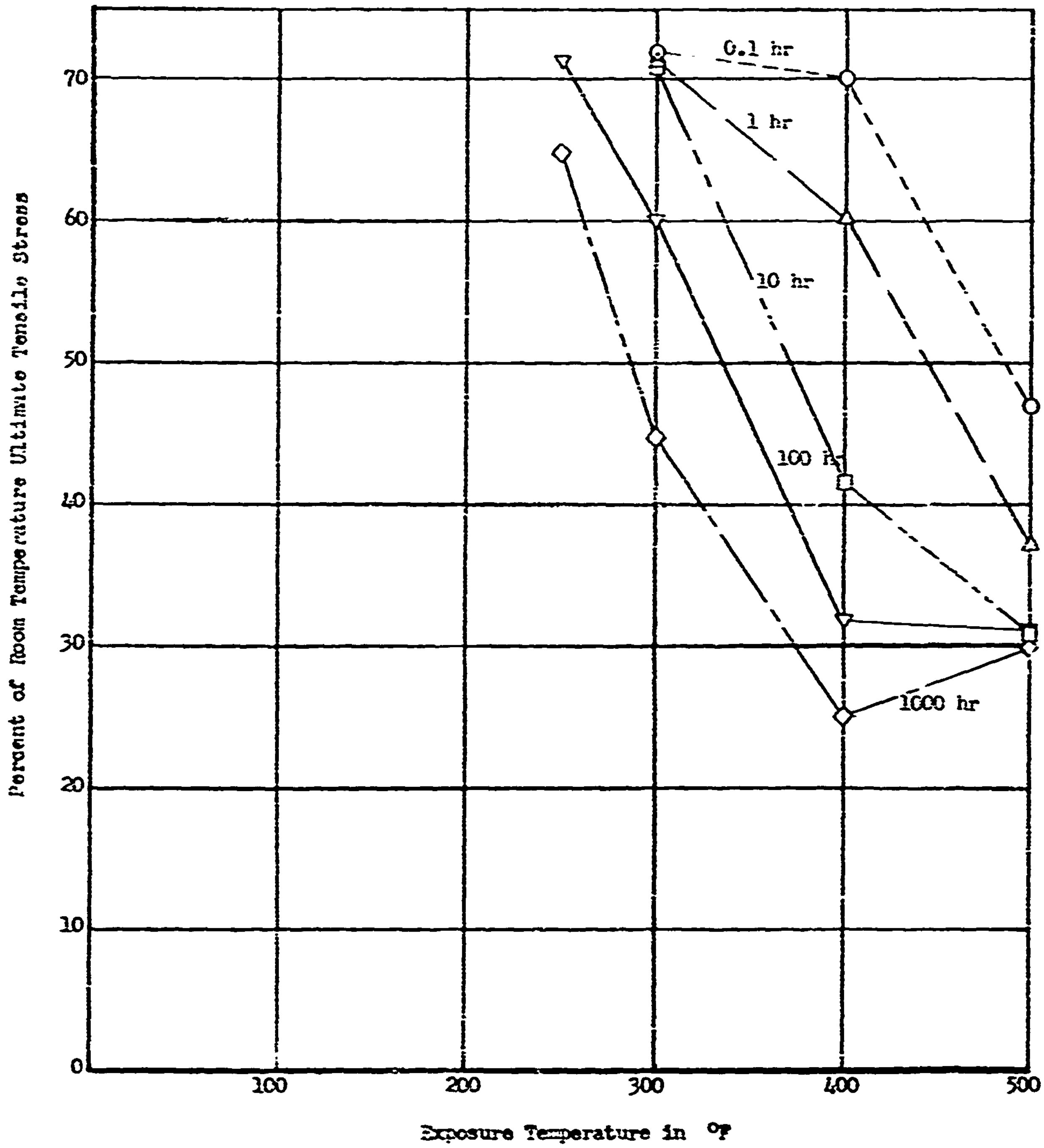

Figure 93. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

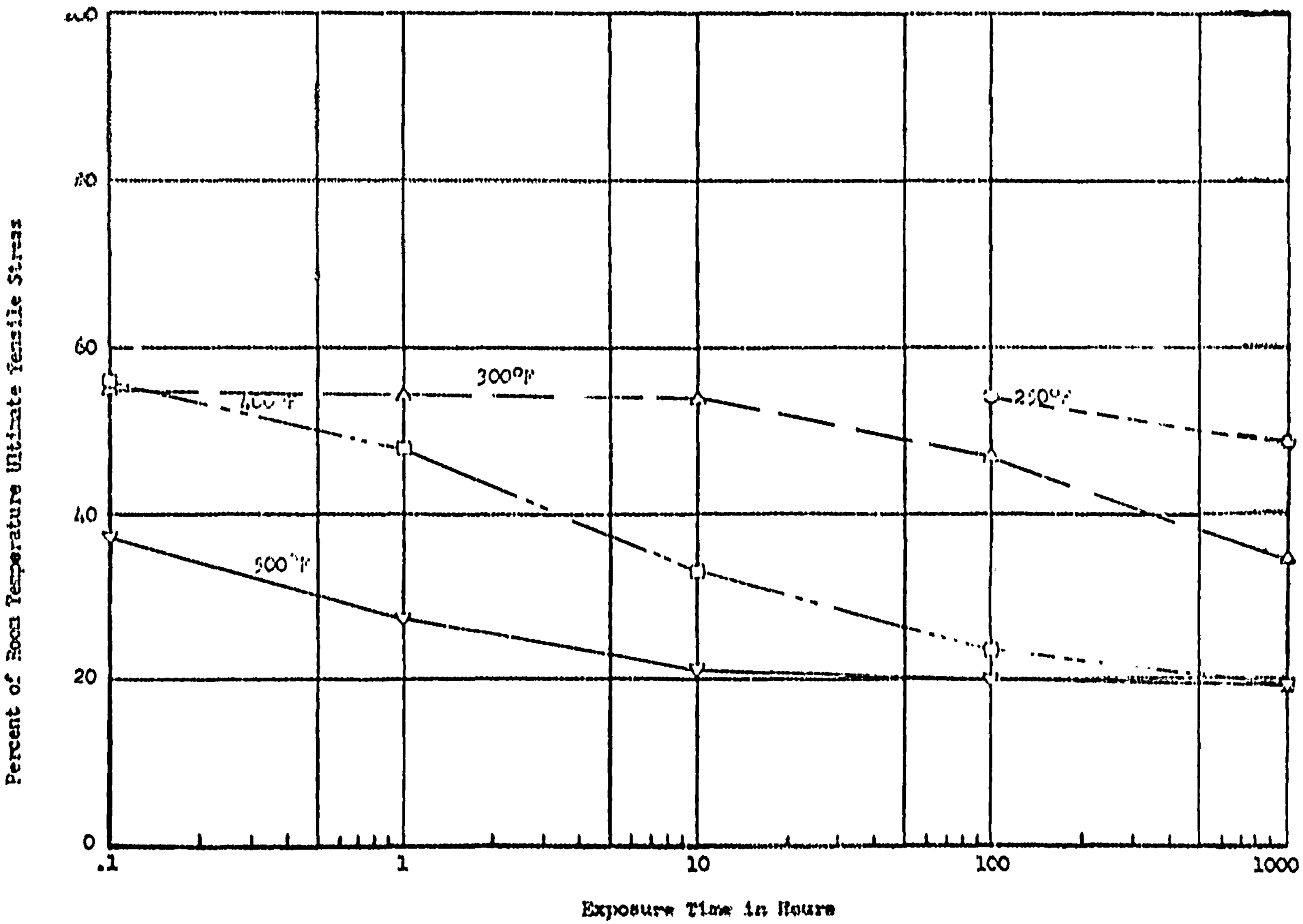

Figure 94. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

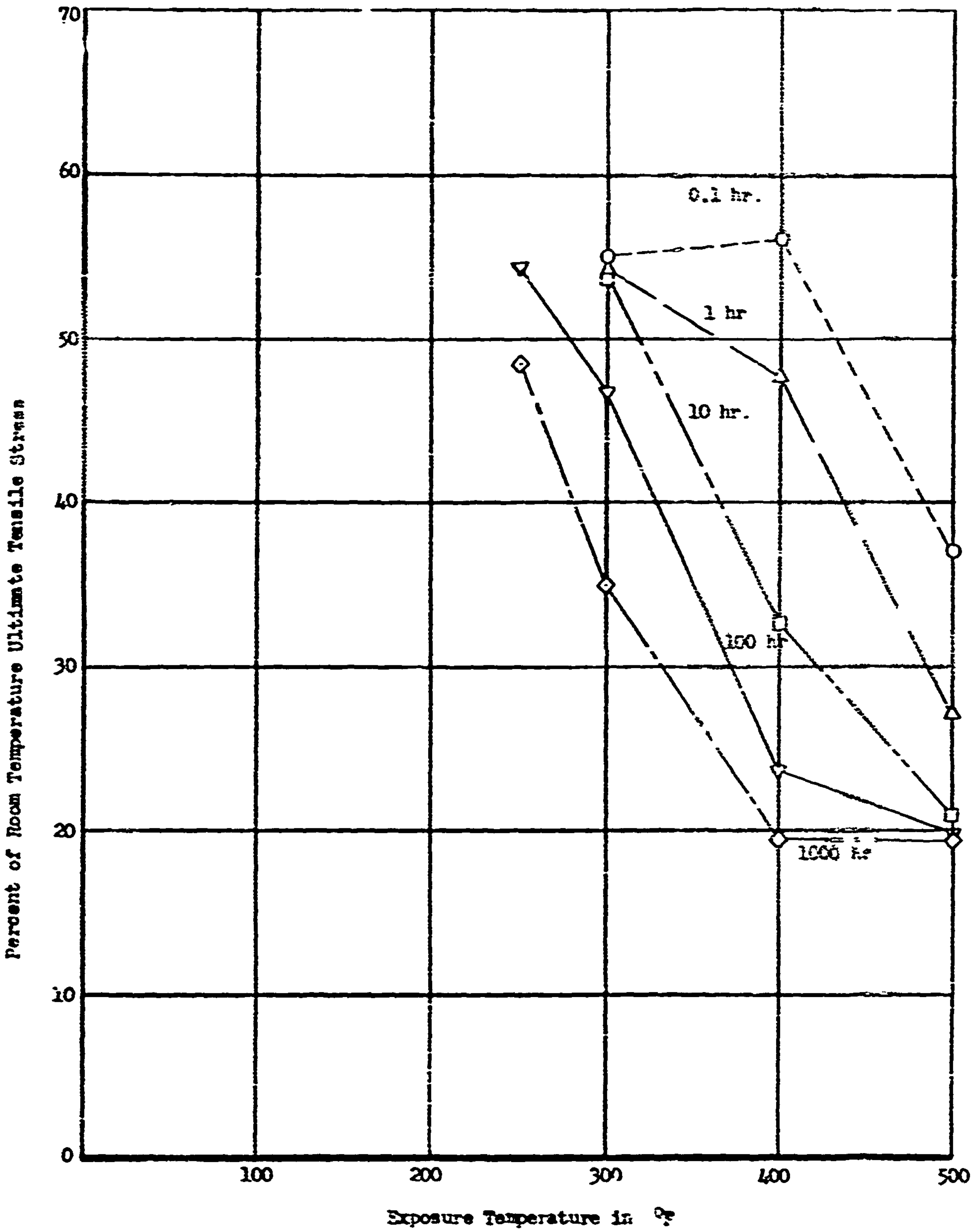

Figure 95. Ultimate Tensile Stress of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

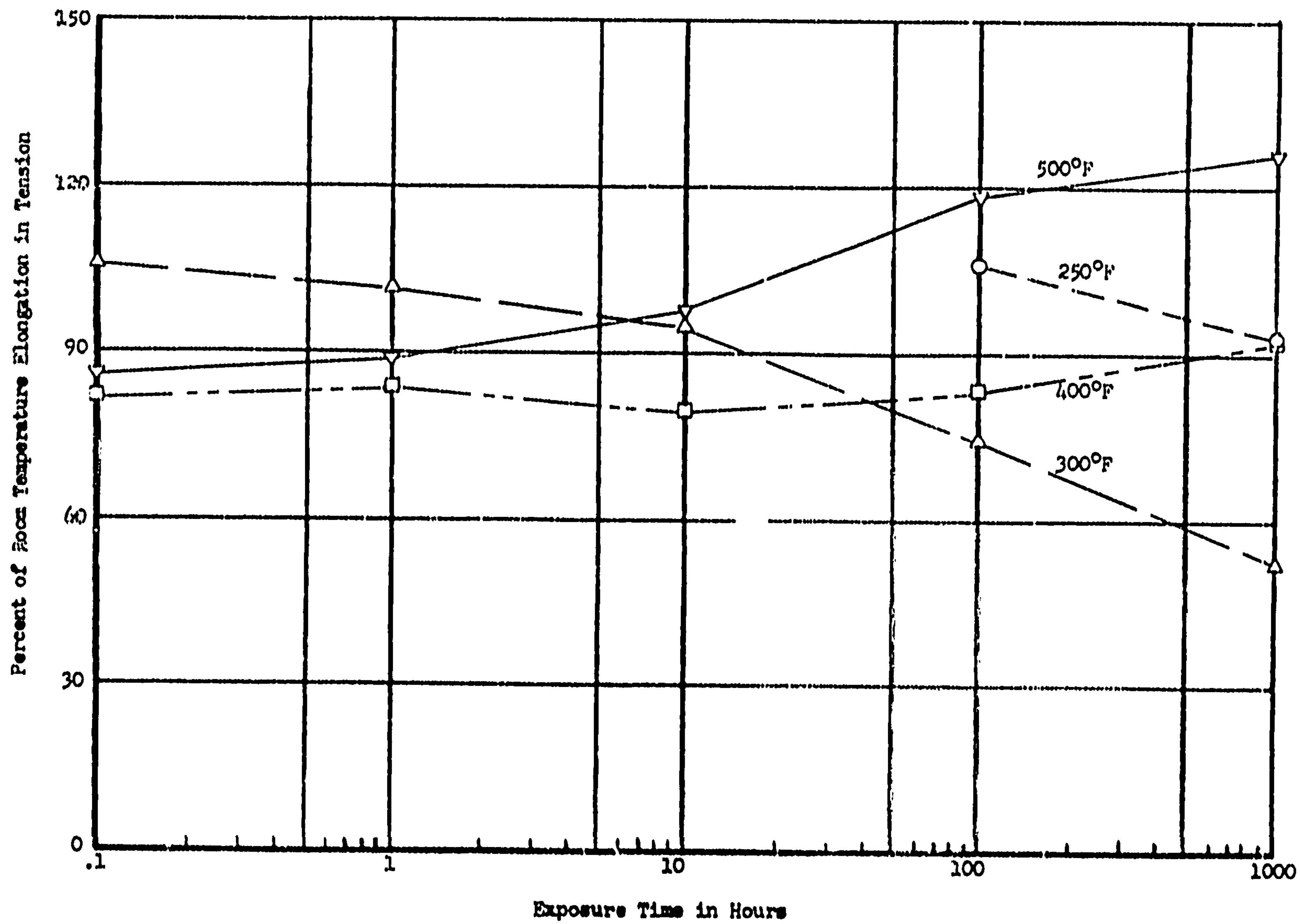

Figure 96. Elongation in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

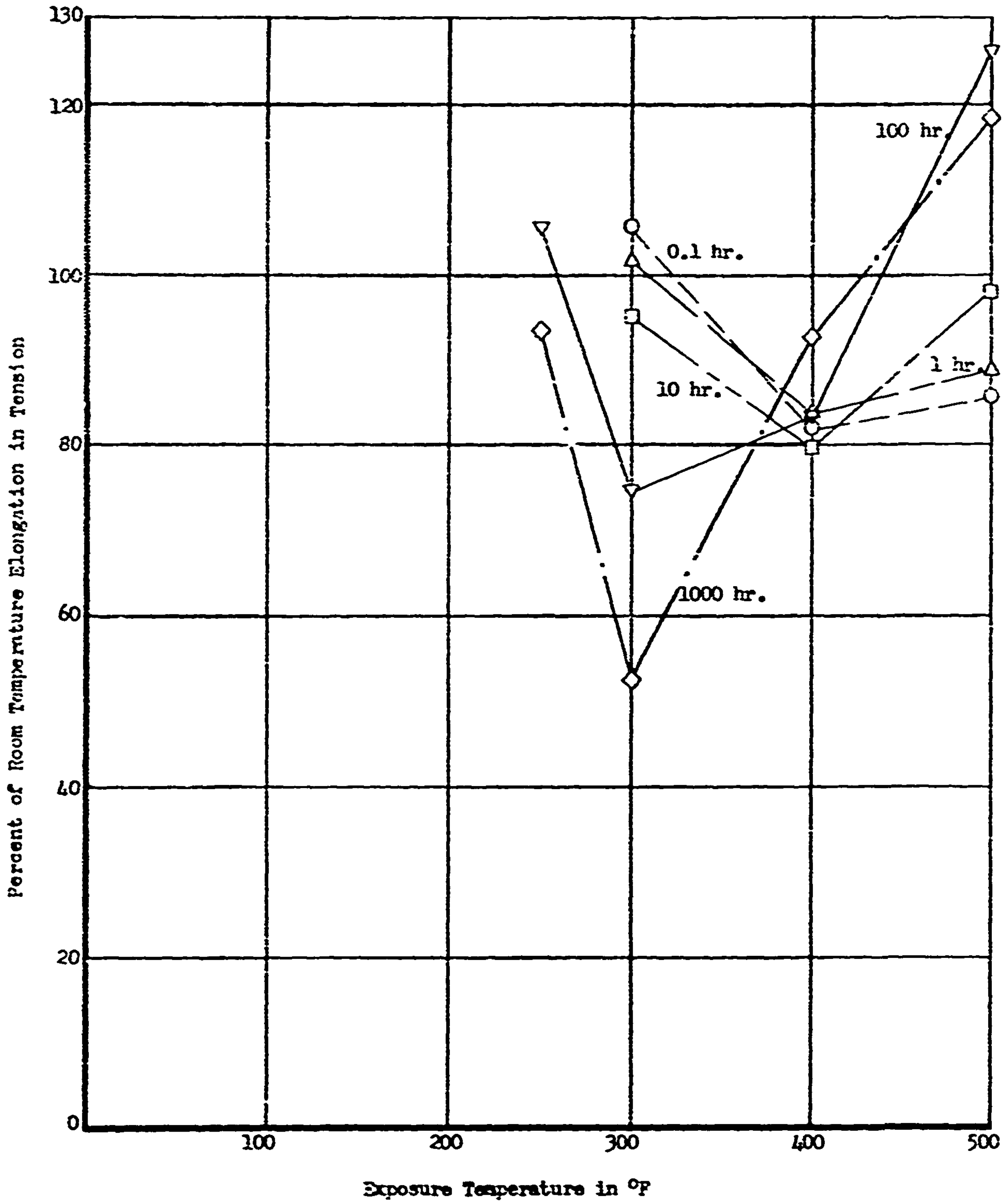

Figure 97. Elongation in Tension of 7075-T6 Clad Sheet at Room Temperature After Exposure to Elevated Temperatures

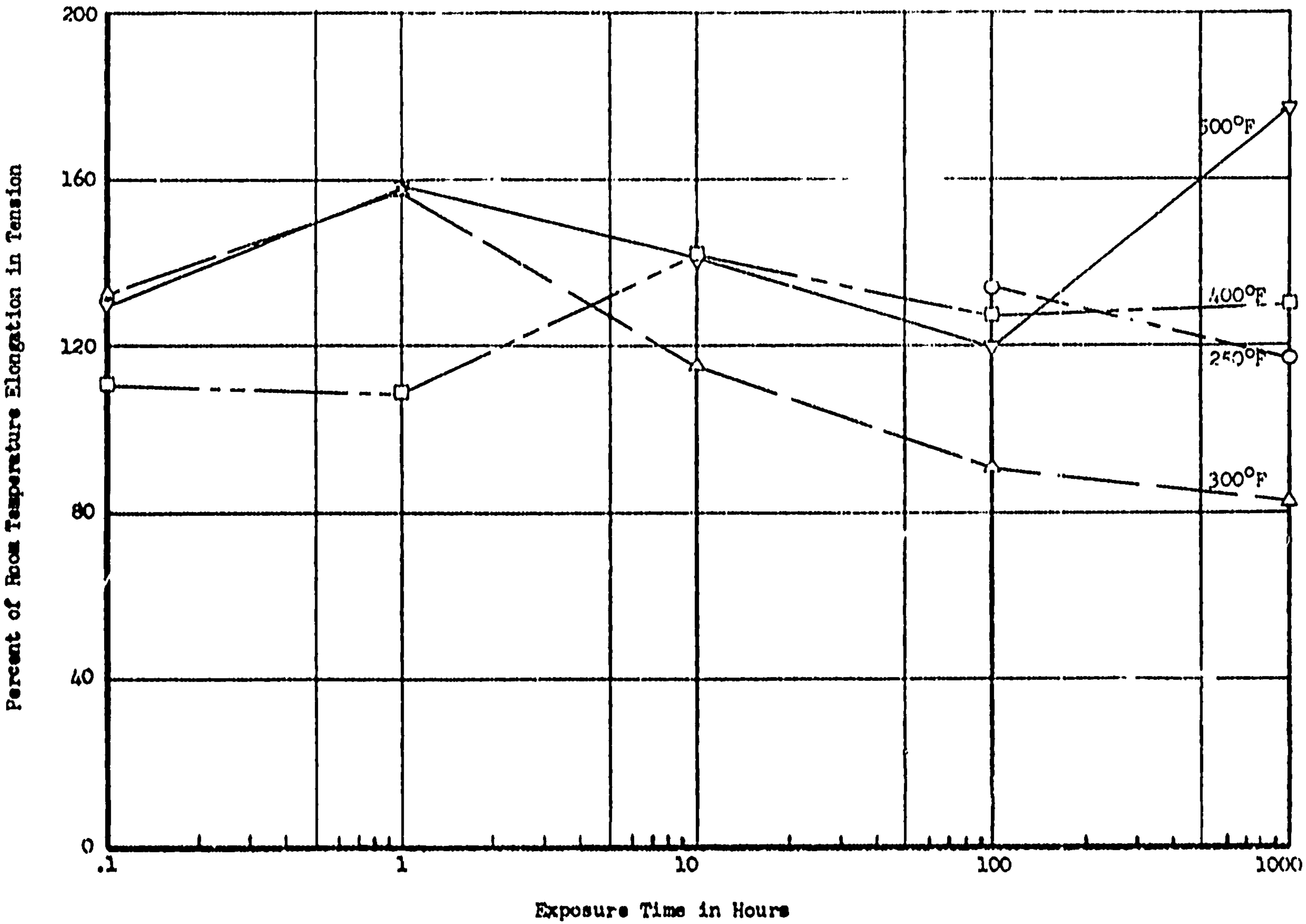

Figure 98. Elongation in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

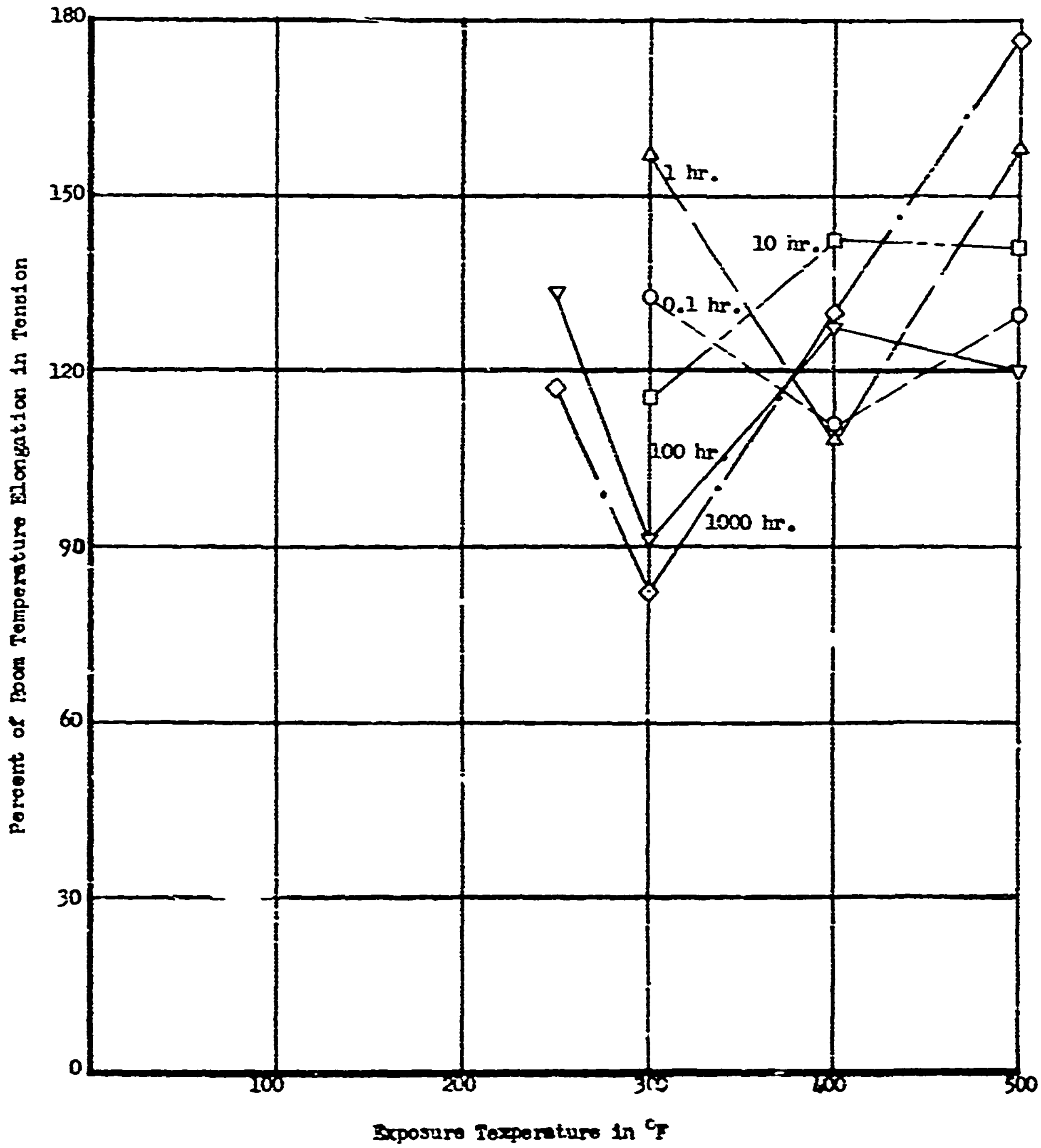

Figure 99. Elongation in Tension of 7075-T6 Clad Sheet at 200°F After Exposure to Elevated Temperatures

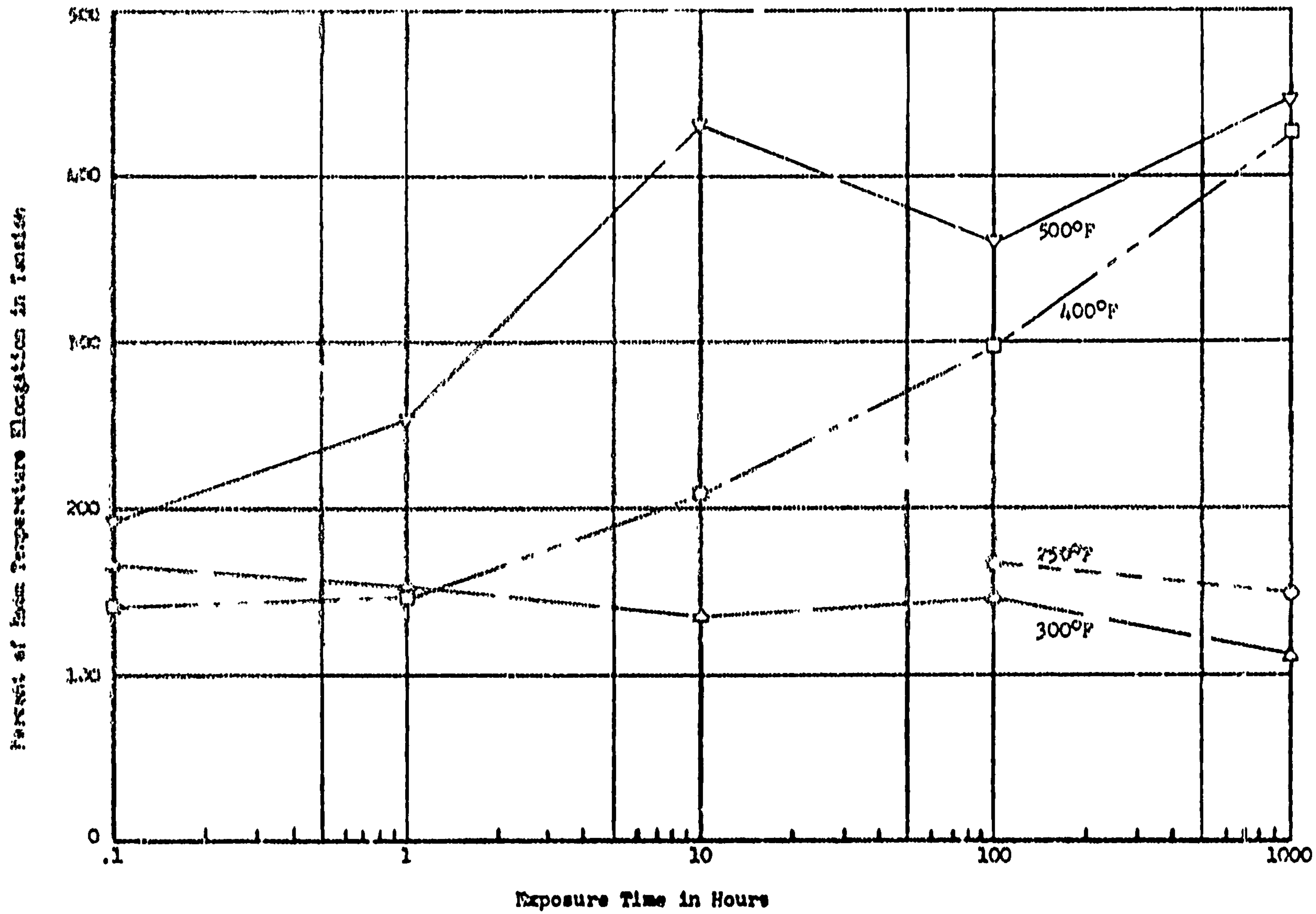

Figure 100. Elongation in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

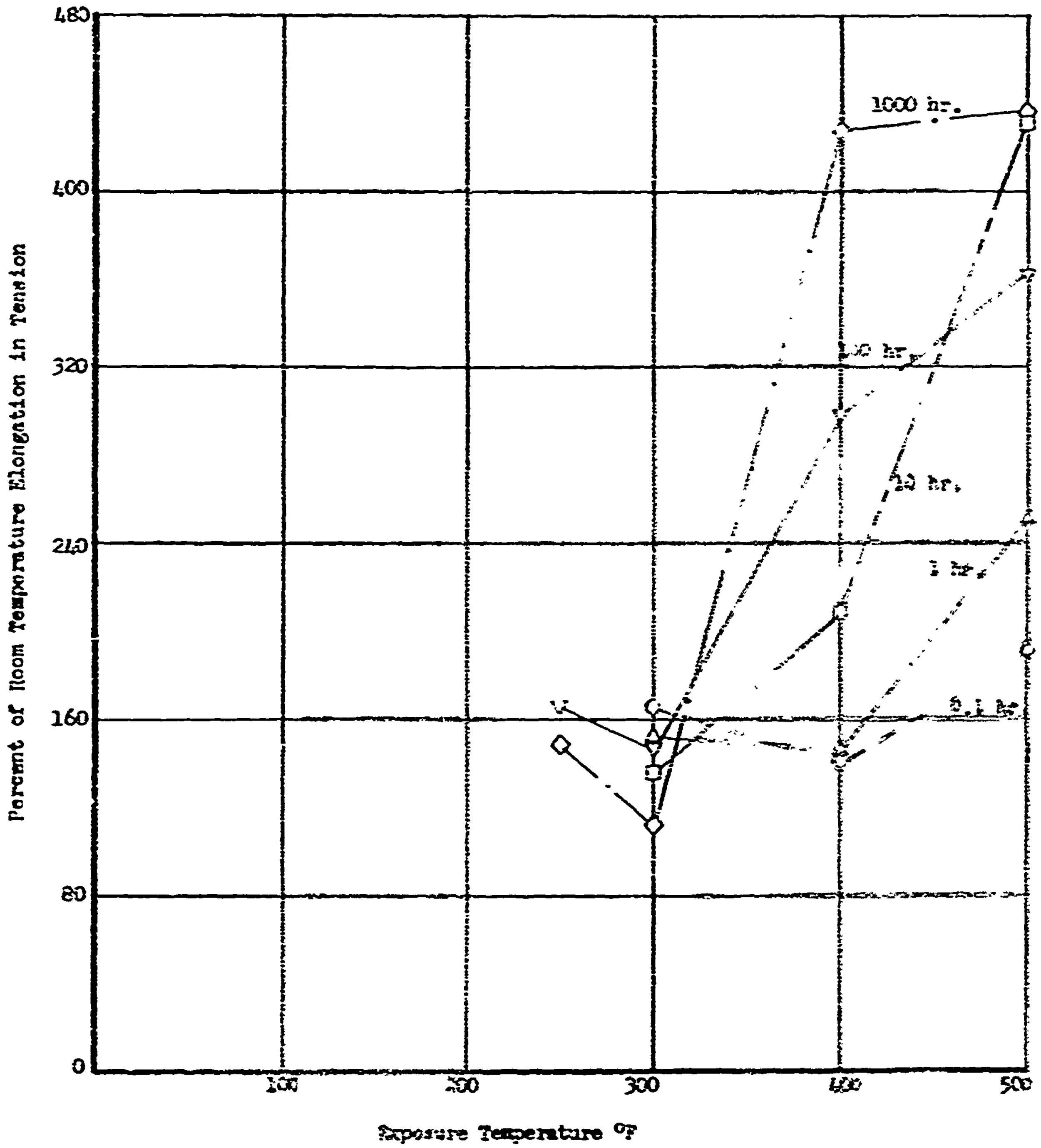

Figure 101. Elongation in Tension of 7075-T6 Clad Sheet at 300°F After Exposure to Elevated Temperatures

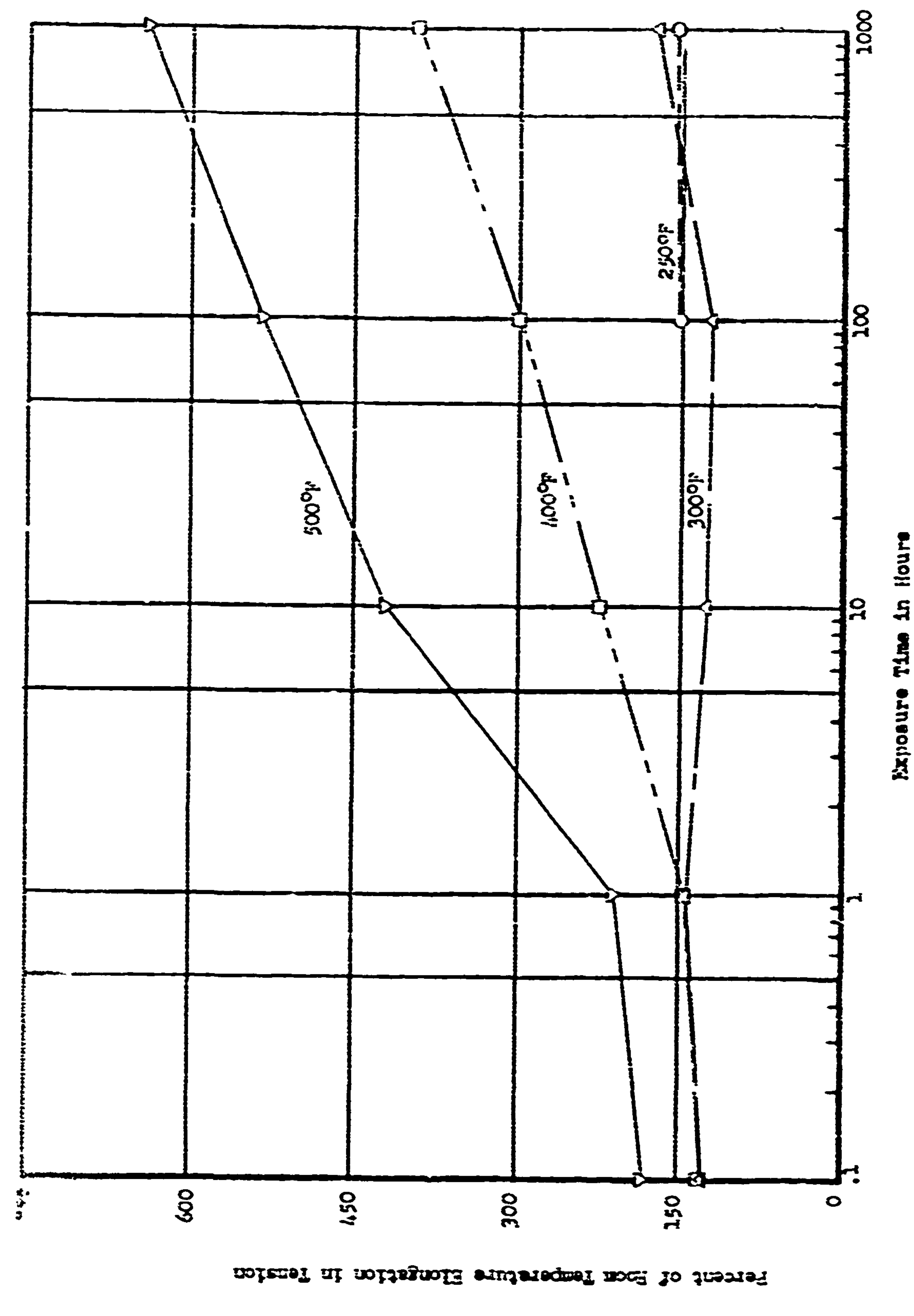

Figure 102. Elongation in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

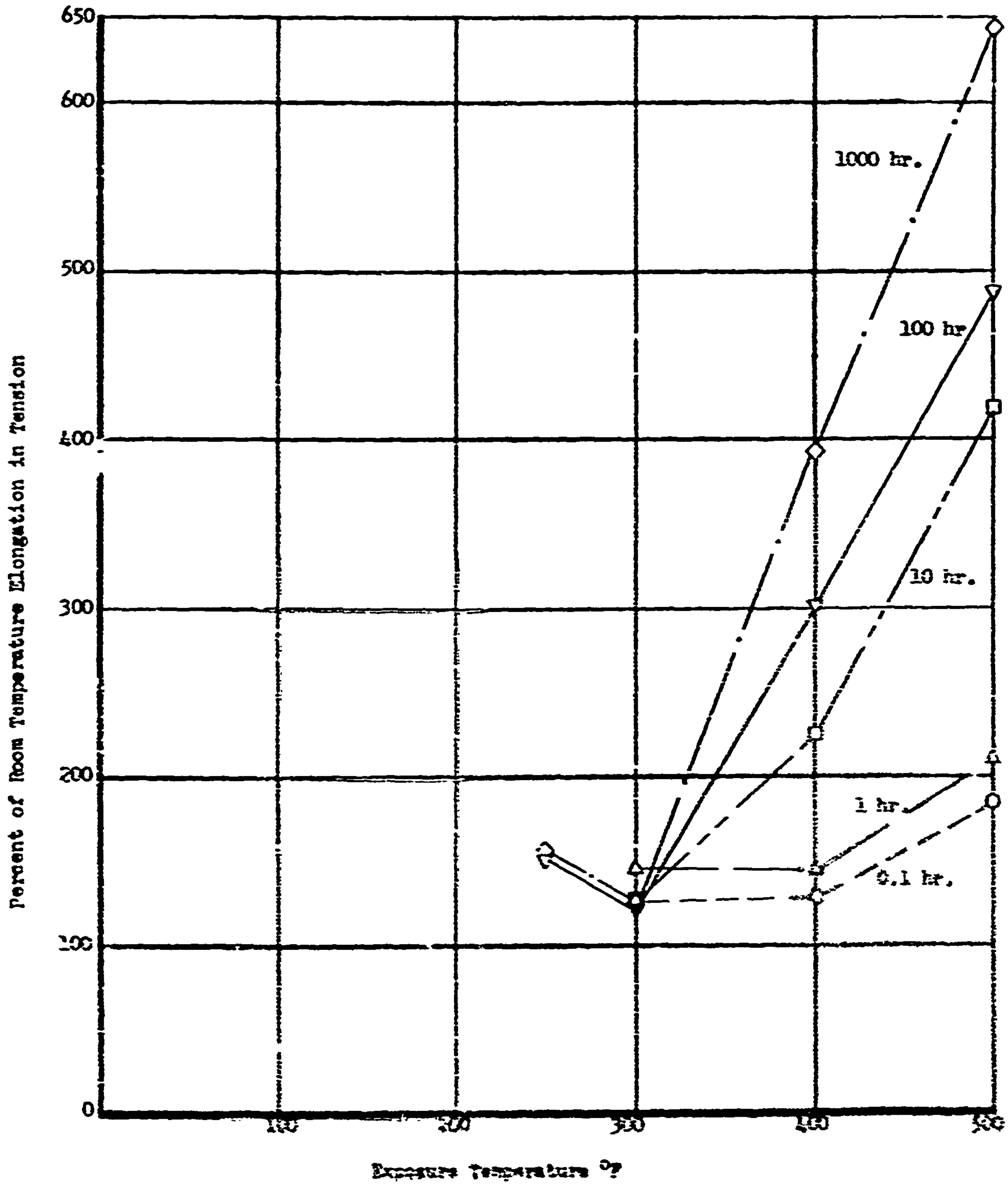

Figure 103. Elongation in Tension of 7075-T6 Clad Sheet at 400°F After Exposure to Elevated Temperatures

TABLE XVII

Tensile Properties of 2024-T3 Alclad Sheet at Room and Elevated Temperature after Exposure at Elevated Temperatures

Exposure Temperature °F	Exposure Time Hours	Testing Temperature °F	Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
			Average Percent of Room Temperature Properties				
--	--	200	90.44	101.03	98.82	95.25	45.0
--	--	300	79.12	97.12	92.83	84.49	116.50
--	--	400	71.92	97.01	77.59	75.79	72.50
300	0.1	R.T.(1)	100.7	101.0	98.0	99.1	93.8
300	0.1	200	92.7	99.7	91.1	92.4	100.1
300	0.1	300	95.0	98.6	89.2	83.4	116.3
300	0.1	400	87.2	94.3	79.5	75.6	98.5
400	0.1	R.T.(1)	62.8	100.0	85.3	92.5	103.8
400	0.1	200	68.9	95.5	84.5	91.0	114.2
400	0.1	300	69.3	95.4	85.0	85.0	117.5
400	0.1	400	100.3	80.0	83.2	75.7	95.0
500(2)	0.1	R.T.	159.7	98.6	119.3	92.9	40.0
500	0.1	200	151.3	94.2	113.2	83.1	44.8
500	0.1	300	130.6	95.0	109.2	73.7	62.1
500	0.1	400	94.8	92.0	93.9	63.6	72.6
600	0.1	R.T.	100.3	97.5	88.2	82.9	44.7
600	0.1	200	121.4	90.9	85.6	78.7	44.3
600	0.1	300	99.4	98.7	83.4	69.4	61.9
600	0.1	400	94.0	90.0	76.1	54.7	81.9
300	1.0	R.T.	110.2	98.5	95.5	96.8	102.4
300	1.0	200	140.3	95.9	93.5	93.1	104.7
300	1.0	300	135.1	93.4	92.1	86.2	117.6
300	1.0	400	132.5	82.9	83.5	73.2	109.8
400(2)	1.0	R.T.	190.4	98.2	124.4	100.3	65.7
400	1.0	200	213.4	95.1	123.3	95.9	72.9
400	1.0	300	210.5	77.2	113.2	88.6	82.4
400(2)	1.0	400	150.0	95.1	110.9	76.4	51.8
500	1.0	R.T.	147.8	96.0	106.9	83.7	37.3
500	1.0	200	135.6	96.6	103.3	82.6	41.9
500	1.0	300	114.5	91.2	97.0	71.4	55.5
500	1.0	400	75.3	91.6	87.7	57.8	71.9
600	1.0	R.T.	56.9	78.5	56.4	67.7	45.3
600	1.0	200	54.0	82.3	56.1	65.9	48.3
600	1.0	300	60.7	84.1	54.0	57.8	80.5
600	1.0	400	60.9	80.2	49.5	41.1	104.0

TABLE XVII (Cont'd)
Tensile Properties of 2024-T3 Alclad Sheet at Room and Elevated Temperature after Exposure at Elevated Temperatures

Exposure Temperature °F	Exposure Time hours	Testing Temperature °F	Average Percent of Room Temperature Properties				
			Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
300	10.0	R.T.(1)	119.6	99.4	97.0	98.5	96.8
300	10.0	200	115.1	101.9	96.8	94.2	98.6
300	10.0	300	104.9	95.6	95.5	87.3	100.9
300	10.0	400	103.5	88.8	78.7	78.7	88.6
400	10.0	R.T.	138.1	102.6	128.8	96.5	35.6
400	10.0	200	177.8	93.4	120.3	87.6	45.4
400	10.0	300	137.1	95.6	110.6	76.3	62.9
400	10.0	400	106.4	91.1	99.1	65.5	61.5
500	10.0	R.T.	98.9	99.8	82.1	78.8	45.7
500	10.0	200	100.4	96.7	80.5	72.9	44.0
500	10.0	300	91.4	89.6	77.4	61.1	80.3
500	10.0	400	87.4	85.7	56.8	47.5	91.9
600	10.0	R.T.	44.7	95.2	40.8	59.4	62.2
600	10.0	200	48.5	102.7	42.3	60.7	55.3
600	10.0	300	53.0	102.2	41.4	52.4	106.7
600	10.0	400	52.5	96.8	38.6	38.2	124.4
300	100.0	R.T.	134.3	99.7	131.9	103.1	58.9
300	100.0	200	175.0	[illegible]	126.5	97.5	53.7
300	100.0	300	152.6	93.4	119.5	83.8	59.5
300	100.0	400	154.6	79.3	108.2	76.8	60.0
400	101.0	R.T.	128.1	94.3	102.5	86.7	41.8
400	101.0	200	134.3	89.3	101.1	79.5	51.5
400	101.0	300	125.5	83.0	93.1	49.5	58.2
400	101.0	400	94.0	91.4	81.2	56.6	67.5
500	100.0	R.T.	57.4	99.1	45.6	58.4	51.3
500	100.0	200	60.5	96.4	44.3	54.3	65.1
500	100.0	300	54.4	91.2	42.5	45.2	105.3
500	100.0	400	51.1	82.4	39.1	33.6	155.2
300	1000.0	R.T.	124.7	101.7	137.5	103.5	38.5
300	1000.0	200	117.4	97.2	128.0	93.5	40.0
300	1000.0	300	94.0	99.5	117.7	82.4	53.5
300	1000.0	400	79.7	94.1	101.8	69.2	61.0
400	1000.0	R.T.	79.2(3)	99.2(3)	75.1(3)	73.0	43.3
400	1000.0	200	48.8	105.5	71.3	63.4	45.3
400	1000.0	300	52.0	94.3	59.8	56.8	61.5
400	1000.0	400	30.9	[illegible]	62.5	45.9	68.0
500	1000.0	R.T.	31.6	103.6	36.0	40.9	64.8
500	1000.0	200	41.6	96.7	35.7	48.2	76.2
500	1000.0	300	32.5	[illegible]	33.3	39.5	140.0
500	1000.0	400	29.3	[illegible]	30.9	27.9	158.9

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.
(2) The percentages corresponding to these exposure temperatures are indicative of original data plus that obtained from retest specimens.
(3) This value represents one specimen only.

TABLE XVIII

Tensile Properties of 7075-T6 Alclad Sheet at Room and Elevated Temperatures after Exposure at Elevated Temperatures

Exposure Temperature °F	Exposure Time Hours	Testing Temperature °F	Average Percent of Room Temperature Properties: Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
--	--	200	119.09	97.65	96.49	90.95	118.04
--	--	300	105.94	93.11	83.73	74.95	137.59
--	--	400	61.41	88.11	60.10	55.14	101.50
300	0.1	R.T.(1)	85.6	100.2	99.8	99.7	105.8
300(2)	0.1	200	80.6	102.5	92.0	89.7	132.5
300	0.1	300	[illegible]	101.0	78.8	72.1	165.3
300	0.1	400	46.2	87.7	59.2	55.0	126.9
400	0.1	R.T.	94.9	98.0	93.4	92.9	92.0
400	0.1	200	98.4	89.9	87.7	85.1	110.8
400	0.1	300	72.8	85.9	77.1	70.0	140.6
400	0.1	400	45.3	85.7	52.5	56.0	128.5
500	0.1	R.T.	45.6	104.3	54.3	67.8	85.8
500	0.1	200	45.2	105.3	54.5	50.5	129.7
500	0.1	300	45.0	98.1	50.5	46.9	191.4
500	0.1	400	29.7	109.6	42.6	37.0	183.3
300	1.0	R.T.	111.1	97.9	94.8	94.4	101.7
300	1.0	200	91.1	95.8	89.7	85.0	156.8
300	1.0	300	101.4	91.7	73.5	71.5	152.6
300	1.0	400	57.4	82.2	60.6	54.3	145.8
400	1.0	R.T.	87.3	101.4	81.4	85.6	83.8
400	1.0	200	72.3	93.0	74.1	72.0	138.5
400	1.0	300	60.0	95.9	67.5	60.2	146.2
400	1.0	400	44.3	81.1	53.3	47.7	143.0
500	1.0	R.T.	36.5	105.8	33.6	57.1	84.7
500	1.0	200	73.1	97.7	38.2	50.5	[illegible]
500	1.0	300	78.1	91.7	36.5	37.3	[illegible]
500	1.0	400	57.1	85.8	31.2	37.1	310.0
300	10.0	R.T.	107.6	100.5	97.8	97.0	94.9
300	10.0	200	125.4	92.4	91.1	86.0	114.4
300	10.0	300	42.4	98.3	77.2	73.3	133.1
300	10.0	400	22.0	94.3	57.7	53.8	126.0
400	10.0	R.T.	58.8	106.3	52.2	64.9	79.7
400	10.0	200	34.4	99.0	49.9	54.4	142.3
400	10.0	300	33.2	107.3	43.6	41.6	228.1
400	10.0	400	42.7	83.0	37.3	32.7	234.4
500	10.0	R.T.	23.8	103.6	27.7	48.4	92.0
500	10.0	200	27.3	107.7	25.7	46.5	140.2
500	10.0	300	26.3	101.0	24.0	31.3	[illegible]
500	10.0	400	23.7	93.1	22.3	20.3	419.1

TABLE XVIII (Cont'd)

Tensile Properties of 7075-T6 Alclad Sheet at Room and Elevated Temperatures after Exposure at Elevated Temperatures

Exposure Temperature °F	Exposure Time Hours	Testing Temperature °F	Average Percent of Room Temperature Properties				
			Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
250	100.0	R.T.(1)	100.1	98.6	97.2	96.4	105.6
250	100.0	200	72.7	103.9	89.9	85.4	133.6
250	100.0	300	64.3	93.5	79.6	71.3	166.4
250	100.0	400	57.9	79.0	60.9	54.3	151.7
300	100.0	R.T.	83.0	96.9	81.7	84.7	74.5
300	100.0	200	81.5	99.2	76.6	72.7	91.0
300	100.0	300	43.1	96.6	67.3	60.0	145.6
300	100.0	400	42.5	86.2	52.6	46.6	121.4
400	101.0	R.T.	33.3	102.6	34.4	50.9	83.6
400(2)	101.0	200	26.9	103.1	33.3	45.1	127.1
400	101.0	300	24.4	100.6	31.2	31.8	297.7
400	101.0	400	18.3	80.9	26.7	23.6	300.7
500	100.0	R.T.	19.7	103.8	23.6	46.5	118.4
500	100.0	200	25.0	105.0	23.7	44.1	120.0
500	100.0	300	22.6	106.3	27.4	31.3	361.6
500	100.0	400	19.7	93.2	20.4	19.9	436.4
250	1000.0	R.T.	91.7	101.0	90.4	92.2	93.5
250	1000.0	200	86.2	95.5	84.6	79.2	117.1
250	1000.0	300	75.3	83.6	72.0	64.9	148.0
250	1000.0	400	26.2	94.4	54.0	48.4	156.1
300	1000.0	R.T.	51.8	99.1	55.9	67.4	52.5
300	1000.0	200	59.4	96.7	55.3	58.4	82.5
300	1000.0	300	49.4	89.1	49.1	44.7	111.5
300	1000.0	400	25.7	88.9	39.2	34.9	124.0
400	1000.0	R.T.	22.2	106.1	25.6	44.1	92.5
400	1000.0	200	18.8	112.6	25.1	39.4	130.1
400	1000.0	300	16.0	116.2	24.0	25.1	427.1
400	1000.0	400	16.3	101.6	21.4	19.4	391.7
500	1000.0	R.T.	20.9	105.4	23.2	41.8	126.0
500	1000.0	200	21.9	111.8	21.5	39.5	176.5
500	1000.0	300	18.8	105.9	20.9	29.3	446.2
500	1000.0	400	22.5(3)	92.3(3)	19.1(3)	19.3	642.3

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) The percentages corresponding to these exposure temperatures are indicative of original data plus that obtained from retest specimens.

(3) This value represents two specimens only.

TABLE XIX

Tensile Properties of 2024-T3 and 7075-T6 Alclad Sheet at Room and Elevated Temperatures after a Sequence of Exposures at Elevated Temperatures

Sequential Exposure Time & Temperature First 1,000 Hr.	Second 1,000 Hr.	Third 1,000 Hr.	Fourth 1,000 Hrs.	Testing Temperature °F	Average Percent of Room Temperature Properties: Proportional Limit	Modulus of Elasticity	Tensile Yield Strength	Tensile Ultimate Strength	Elongation
					2024-T3 Alclad Sheet Properties				
[illegible]	[illegible]	--	--	R.T.(1)	104.5	99.0	150.5	87.5	35.4
[illegible]	[illegible]	--	--	200	138.8	58.7	103.2	60.5	48.3
[illegible]	[illegible]	--	--	300	127.1	69.6	95.4	68.8	69.5
[illegible]	[illegible]	--	--	400	104.2	84.7	83.7	57.7	69.0
[illegible]	[illegible]	[illegible]	--	R.T.	125.4	96.3	106.7	87.8	44.3
[illegible]	[illegible]	[illegible]	--	200	143.8	66.3	103.8	80.4	49.3
[illegible]	[illegible]	[illegible]	--	300	112.9	58.7	93.1	68.2	64.0
[illegible]	[illegible]	[illegible]	--	400	174.0	77.8	91.3	56.7	76.4
500	500	--	--	R.T.	52.9	93.6	60.9	66.3	42.9
500	[illegible]	--	--	200	54.4	55.3	56.3	61.8	49.8
600	[illegible]	--	--	300	47.6	54.0	53.5	50.8	68.3
600	[illegible]	--	--	400	40.5	87.7	48.8	38.4	87.8
[illegible]	500	[illegible]	--	R.T.	54.0	95.9	56.4	62.3	46.8
[illegible]	[illegible]	[illegible]	--	200	43.1	102.8	51.2	54.9	52.8
600	[illegible]	400	--	300	35.8	111.7	49.4	44.4	78.0
600	[illegible]	400	--	400	35.4	98.7	46.4	37.3	82.1
[illegible]	500	400	300	R.T.	28.3	98.1	64.4	43.1	51.9
[illegible]	500	400	300	200	38.5	71.3	54.4	37.4	62.5
[illegible]	[illegible]	400	300	300	55.1	91.3	54.3	49.4	79.3
600	500	400	300	400	39.2	91.1	47.7	19.7	80.3
					7075-T6 Alclad Sheet Properties				
400	300	--	---	R.T.(1)	90.3	85.9	74.8	84.1	90.1
400	300	--	---	200	77.7	82.9	76.5	73.9	115.6
400	300	--	---	300	69.6	76.0	66.2	58.6	155.7
400	300	--	---	400	40.7	88.7	52.4	46.3	161.0
400	300	250	---	R.T.	82.9	95.8	79.4	83.9	80.9
400	300	250	---	200	84.1	99.0	76.9	72.7	100.7
400	300	250	---	300	66.7	91.6	66.5	57.8	130.4
400	300	250	---	400	44.5	90.0	53.1	46.7	145.5
500	400	--	---	R.T.	30.5	106.7	37.5	54.1	79.7
500	400	--	---	200	34.8	97.5	37.0	46.9	153.1
500	400	--	---	300	27.2	100.0	34.7	33.3	275.0
500	400	--	---	400	21.5	109.8	29.3	25.4	271.9
500	400	300	---	R.T.	27.0	114.6	38.7	53.7	83.6
500	400	300	---	200	13.4	97.3	37.7	47.7	146.1
500	400	300	---	300	29.8	109.3	35.0	33.1	260.2
500	400	300	---	400	22.6	95.0	29.1	25.3	251.6
500	400	300	250	R.T.	13.2	125.4	38.4	51.4	85.6
500	400	300	250	200	14.2	103.7	34.9	44.3	148.0
500	400	300	250	300	30.3	94.7	34.1	32.4	256.0
500	400	300	250	400	[illegible]	94.2	29.9	24.2	235.0

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 65-85°F.

TABLE XX

Tensile Properties of 2024-T3 and 7057-T6 Alclad Sheet at Room and Elevated Temperatures after an Additional Sequence of Exposures at Elevated Temperatures.

Sequential Exposure Time and Temperature				Testing	Average Percent of Room Temperature Properties				
First	Second	Third	Fourth	Temperature °F	Proportional Limit	Modulus of Elasticity	Yield Strength	Ultimate Strength	Elongation
2024-T3 Alclad Sheet Properties									
1.0Hr	5.0Hrs	30.0Hrs	219.0Hrs						
465°F	420°F	375°F	330°F	R. T.(1)	168.3	102.2	127.2	99.0	38.9
465	420	375	330	200	137.0	101.6	117.7	88.9	49.0
465	420	375	330	300	126.1	100.5	108.9	76.5	60.6
465	420	375	330	400	95.9	99.4	95.9	[illegible]	[illegible]
1.0Hr	4.6Hrs	25.2Hrs	164.0Hrs						
510°F	465°F	420°F	375°F	R. T.	164.3	100.9	101.6	86.6	[illegible]
510	465	420	375	200	106.1	96.7	92.0	75.4	52.1
510	465	420	375	300	130.3	94.3	83.8	[illegible]	63.8
510	465	420	375	400	109.4	88.3	74.6	[illegible]	68.1
1.0Hr	[illegible]	21.5Hrs	126.1Hrs						
555°F	[illegible]	465°F	420°F	R. T.	85.6	99.3	68.2	[illegible]	51.3
555	[illegible]	465	420	200	77.6	96.4	65.3	[illegible]	[illegible]
[illegible]	[illegible]	465	420	300	83.1	96.2	61.1	[illegible]	[illegible]
555	[illegible]	465	120	400	79.2	94.9	[illegible]	[illegible]	81.5
1.0Hr	[illegible]	[illegible]	99.6Hrs						
600°F	[illegible]	510°F	465°F	R. T.	71.4	98.9	31.7	[illegible]	[illegible]
[illegible]	555	510	465	200	67.5	96.3	43.3	[illegible]	[illegible]
[illegible]	555	[illegible]	465	300	59.9	95.3	[illegible]	44.4	81.3
600	555	[illegible]	465	400	48.5	89.5	39.2	33.4	109.3
7075-T6 Alclad Sheet Properties									
1.0Hr	4.6Hrs	27.6Hrs	191.7Hrs						
380°F	340°F	300°F	260°F	R. T.	76.41	101.18	80.72	[illegible]	96.0
[illegible]	340	300	260	200	101.79	99.40	79.19	[illegible]	118.33
[illegible]	[illegible]	300	260	300	107.82	97.62	72.94	[illegible]	147.50
380	340	300	260	400	86.74	95.04	[illegible]	[illegible]	131.66
[illegible]	4.5Hrs	23.4Hrs	155.1Hrs						
420°F	380°F	340°F	300°F	R. T.	55.9	99.8	56.2	63.6	[illegible]
420	380	340	300	[illegible]	57.9	101.3	53.7	[illegible]	126.6
420	[illegible]	340	300	[illegible]	48.3	97.7	[illegible]	[illegible]	185.5
420	380	340	300	[illegible]	32.2	104.3	[illegible]	33.5	[illegible]
1.0Hr	4.7Hrs	[illegible]	113.4Hrs						
460°F	[illegible]	380°F	340°F	R. T.	39.9	102.3	41.8	56.7	75.7
[illegible]	[illegible]	380	340	200	42.4	104.3	[illegible]	47.9	121.2
[illegible]	420	380	340	300	34.9	98.9	[illegible]	34.7	136.9
[illegible]	420	380	340	400	35.5	[illegible]	32.8	28.0	197.7
1.0Hr	4.0Hrs	17.5Hrs	90.5Hrs						
500°F	460°F	420°F	380°F	R. T.	33.2	101.3	[illegible]	48.2	[illegible]
500	[illegible]	420	380	200	33.7	102.5	29.5	43.4	137.1
500	460	420	380	300	28.0	[illegible]	[illegible]	[illegible]	[illegible]
500	460	420	380	400	26.2	[illegible]	[illegible]	[illegible]	[illegible]

(1) R. T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

TABLE XXI

ROOM TEMPERATURE ROCKWELL HARDNESS OF .064 GAGE 2024-T3 ALCLAD SHEET AFTER VARIOUS TEMPERATURE-TIME EXPOSURE CONDITIONS

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R_B	R_H
2A1	15380	33860		96.5
2A2	15670	34710		95.9
2A3	15560	34440		97.0
2C29	51730	67[illegible]0	78.0	
2C30	51560	68280	77.4	
2C31	46850	60410	65.1	
2C32	46860	60380	65.8	
2C33	47150	60440	66.4	
2D7	25630	45560	40.4	103.8
2D8	24760	45770	39.1	103.1
2D9	24290	45450	38.2	103.3
2E7	37930	63320	70.6	
2E8	38050	63370	71.0	
2E9	38050	63520	69.5	
2F9	50000	62040	70.9	
2F10	49070	61800	68.6	
2G9	39050	56090	61.5	110.9
2G10	39340	55960	60.0	111.0
2G11	38870	55900	58.0	110.9
2J1	18120	39660	23.4	98.9
2J4	17690	39340	25.8	98.9
2J5	17590	39820	23.0	97.6
2K4	36010	52830	54.8	109.1
2K5	35940	52810	54.1	109.6
2K6	35830	52650	55.1	109.8
2L4	56830	65530	74.9	
2L5	56680	65530	74.9	
2L6	56270	65370	74.0	
2M4	21010	40640	27.6	102.5
2M5	20060	39740	26.3	100.0
2M6	19940	39260	24.1	101.1
2N5	46590	59440	68.0	
2N6	46630	59360	67.4	
2N7	46930	59510	68.5	
2P6	59820	71170	79.6	
2P7	59630	70950	80.8	
2P8	59230	70770	79.7	117.0
2V1	33790	49850		108.7
2V2	--	49540		108.3
2V3	--	49690		109.6
2W1	46260	59500	67.3	
2W2	46570	59500	68.5	
2W3	47660	60120	68.7	

TABLE XXI (Cont'd)

Room Temperature Rockwell Hardness of .064 Gage 2024-T3 Alclad Sheet After Various Temperature-Time Exposure Conditions

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R_B	Hardness R_H
2X1	46900	59440	66.0	
2X2	47830	59910	67.8	
2X3	48610	60490	68.2	
2Y12	42300	66460	69.4	
2Z1	61540	68920	77.0	
2Z2	61460	69350	76.9	
2Z3	61880	69690	78.3	
2AA1	27160	45370	35.6	105.6
2AA2	25700	45170	40.0	104.3
2AA3	26180	45300	34.0	105.6
2BB1	27430	44670		103.1
2BB2	25690	43080		102.8
2BB3	24140	41510		101.8
2CC1	27390	44190	39.0	104.3
2CC2	27280	44340	41.5	104.9
2CC3	25630	43750	40.2	104.1
2DD2	41850	65850	68.3	
2DD3	41570	66820	68.8	
2EE1	41240	66360	69.0	
2EE2	41730	66670	69.4	
2EE3	41390	67230	70.1	
2HH1	30230	47210	41.6	105.7
2HH2	29970	47050	42.1	105.7
2HH3	30160	47340	42.2	107.0
2II1	23300	43210	15.9	99.3
2II2	22600	41950	14.9	97.7
2II3	21740	41300	16.6	99.1
2JJ1	56720	67500	70.3	114.3
2JJ2	55630	66720	70.6	114.4
2JJ3	55510	66980	71.1	114.4
2KK1	44450	59330	60.1	111.4
2KK2	44110	58920	59.3	112.0
2KK3	43310	56690	58.4	112.0
2AC1	42830	68470	71.0	
2AC2	43550	66510	70.9	
2BC1	42970	67500	71.2	
2BC2	43300	67450	71.1	
2CC1	43770	68230	71.8	
2CC2	44100	68010	71.4	
2DC1	44220	67340	71.5	
2DC2	44030	68240	71.5	
2EC1	44550	68540	71.6	
2EC2	44530	68590	71.4	
2FC2	44700	68540	71.7	
2GC1	44250	67550	70.3	
2GC2	44380	67500	69.4	

TABLE XXI (Cont'd)

Room Temperature Rockwell Hardness of .064 Gage 2024-T3 Alclad Sheet After Various Temperature-Time Exposure Conditions

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R_B	Hardness R_H
2HC1	44380	67810		112.5
2HC2	44080	67910	70.2	
2IC1	44980	68810	71.3	
2IC2	44670	68970	71.6	
2JC1	43610	66510	69.8	
2JC2	43610	66670	70.2	
2KC1	43690	66620	69.5	
2KC2	43830	67280	70.0	
2LC1	43940	67550	72.2	
2LC2	43960	67790	70.9	
2MC1	43830	67750	70.9	
2MC2	43400	67790	70.9	
2NC1	44750	68670	69.7	
2NC2	44460	68460	71.2	
2OC1	45220	68980	71.5	
2OC2	45120	69140	71.3	
2PC1	45500	69560	71.4	
2PC2	44780	68100	70.1	
2QC1	45120	68210		112.0
2QC2	44920	68310		113.3

TABLE XXII

ROOM TEMPERATURE ROCKWELL HARDNESS OF .064 GAGE 7075-T6 ALCLAD SHEET AFTER VARIOUS TEMPERATURE-TIME EXPOSURE CONDITIONS

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R_B	Hardness R_H
7A1	14050	32840		92.6
7A2	13980	32300		92.3
7A3	14200	32790		91.3
7C34	54060	65910	73.3	115.8
7C35	53770	65900	74.6	115.5
7D21	54370	66340	72.4	114.8
7D22	25570	44140	37.3	105.1
7D23	25650	44160	35.6	104.8
7D28	25820	44240	36.2	104.9
7F38	62540	72640	77.6	
7F39	62700	72800	79.5	
7F40	62700	72830	78.6	
7G8	36170	53380	55.5	110.0
7H1	36130	53550	56.1	110.4
7H2	35970	51610	53.6	109.6
7I4	65600	76910	81.0	
7I5	65820	77160	79.3	
7I6	65500	77000	80.5	
7K7	63220	74840	80.3	
7K8	63690	75640	79.1	116.3
7L1	63060	71340	81.5	
7M6	18330	37780		97.8
7M8	18430	37980		98.0
7O4	64080	75000	81.0	
7P1	66020	76210	81.5	116.6
7P11	65760	76210	81.2	
7P12	23310	40190		102.0
7P13	23310	40030		102.3
7Q1	35060	50650	55.0	109.4
7Q2	35110	50810	53.7	109.5
7Q3	34790	50320	53.8	109.1
7T2	56010	66610	75.6	
7T3	55950	66610	74.9	
7T4	55710	66510	73.5	
7U3	67340	76560	81.9	
7U4	67340	76560	82.3	
7U5	67500	76720	81.0	
7V4	54660	65970	74.1	
7V5	55350	66670	75.3	
7W3	53260	64540	74.4	
7W4	53630	64950	74.0	
7W5	55290	66190	73.4	

TABLE XXII (Cont'd)

Room Temperature Rockwell Hardness of .064 Gage 7075-T6 Alclad Sheet After Various Temperature-Time Exposure Conditions

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R_B	Hardness R_E
7A3	20100	[illegible]		96.8
7X9	17800	37740		96.9
7X10	17700	37500		97.0
[illegible]	17270	34760		95.7
7Y2	17650	34920		95.4
7Y3	17410	34650		93.0
7Z1		72900	83.7	
7Z2	61610	72740	81.8	
7Z3	62020	72440	[illegible]	
7AA1	[illegible]	42880	[illegible]	103.8
7AA2	25840	43120	33.8	104.3
7AA3	[illegible]	43060	33.2	103.7
7BB1	26700	42720		102.1
7BB2	26500	42930		104.0
7BB3	26590	42930		103.7
7CC1	26530	42280	28.3	103.6
7CC2	26350	42470	30.6	102.7
7CC3	26200	42330	26.6	103.7
7DD1			81.2	116.4
7DD2			80.9	116.2
7EE1	37820	52220	59.6	111.0
7EE2	38170	52370	59.5	110.3
7EE3	38660	52500	59.6	110.3
7FF1	15450	35670		94.4
7FF2	15290	35190		95.0
7FF3	15190	35130		94.6
7GG1	20350	36790	23.0	101.1
7GG2	20690	37260	15.8	101.1
7GG3	20630	37190	20.3	101.0
7HH1	27270	43450	41.9	106.0
7HH2	27520	43460	39.5	106.1
7HH3	27340	43450	39.5	106.3
7II1	52340	68990	80.0	106.0
7II2	62160	68040	81.5	105.5
7II3	61830	69400	81.6	106.4
7JJ1	38880	52540	57.2	110.8
7JJ2	38690	52870	55.0	111.0
7JJ3	38400	52510	54.9	110.6
7AC2	66720	78310	83.2	
7BC1	66520	77450	83.4	
7BC2	66890	77710	82.5	
7CC1	66010	76970	80.8	
7CC2	66060	76850	81.8	

TABLE XXII (Cont'd)

ROOM TEMPERATURE ROCKWELL HARDNESS OF .064 GAGE 7075-T6 ALCLAD SHEET AFTER VARIOUS TEMPERATURE-TIME EXPOSURE CONDITIONS

Specimen Number	Yield Strength psi	Ultimate Strength psi	Hardness R_B	R_H
7DC1	66240	77330	81.4	
7DC2	65720	77650	82.4	
7EC1	66940	78550	80.6	
7EC2	66720	77920	81.3	
7FC1	67590	78500	80.3	
7FC2	66550	78130	80.3	
7GC1	66820	77880	80.4	
7GC2	66450	77900	79.8	
7HC1	66880	78130	81.1	
7HC2	66020	77880	82.3	
7IC1	65890	77860	79.0	
7IC2	65640	76610	79.9	
7JC1	67250	77850	83.0	
7JC2	67250	77850	82.0	
7KC1	67900	78230	80.6	
7KC2	66940	78500	81.7	
7LC1	66500	78320	81.2	
7MC1	65320	77440	82.2	
7PC1	67470	78690	83.5	
7PC2	67420	78780	83.8	
7QC2	67040	77920	83.2	
7RC2	67850	78520	83.8	
7SC1	67420	79520	81.8	
7SC2	68310	79420	81.5	
7TC1	68210	78430	80.8	
7TC2	68690	78750	81.3	
7UC1	69400	79500	81.3	
7UC2	69240	79500	81.0	

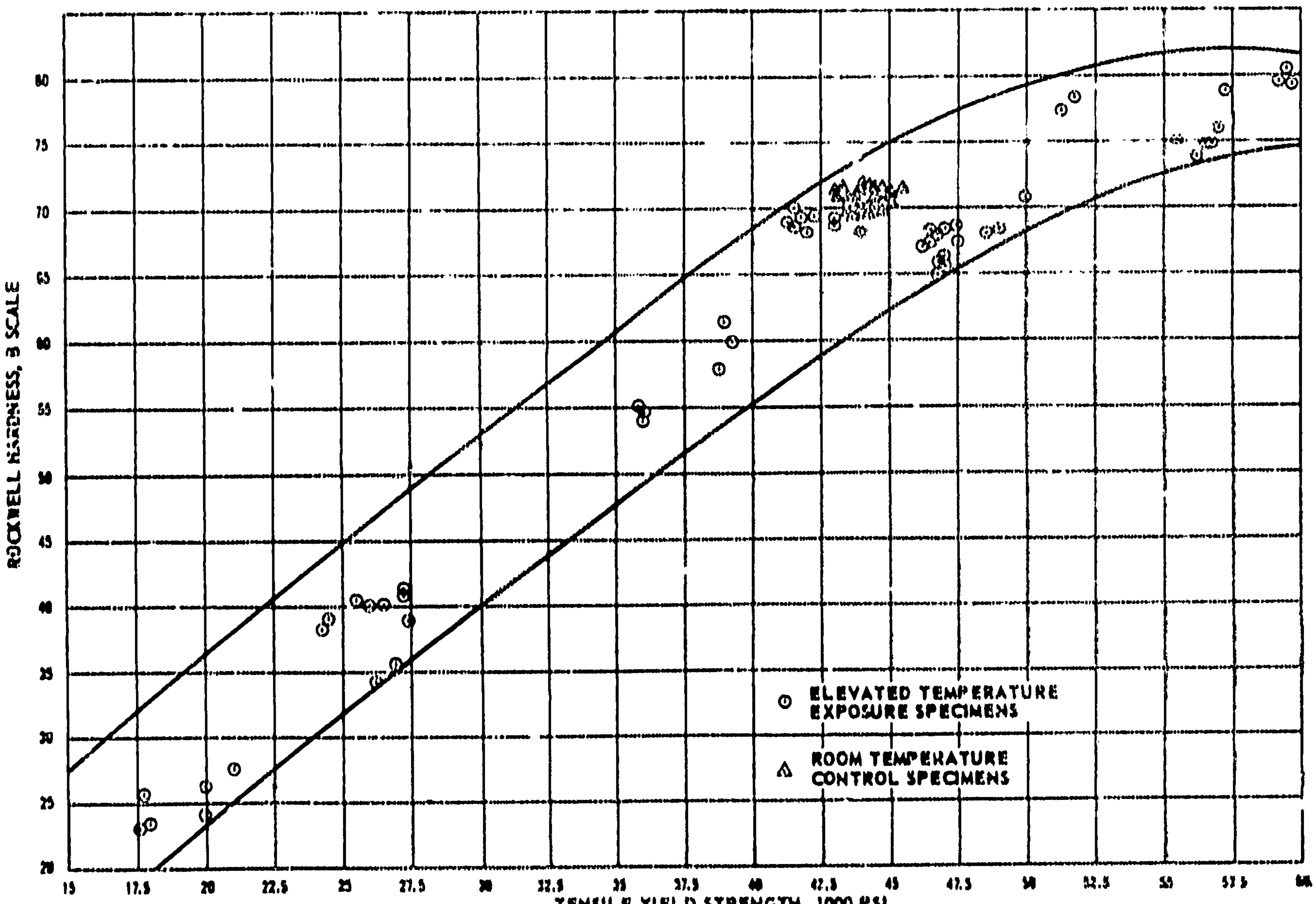

FIGURE 104 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 2024-T3 ALUMINUM ALLOY

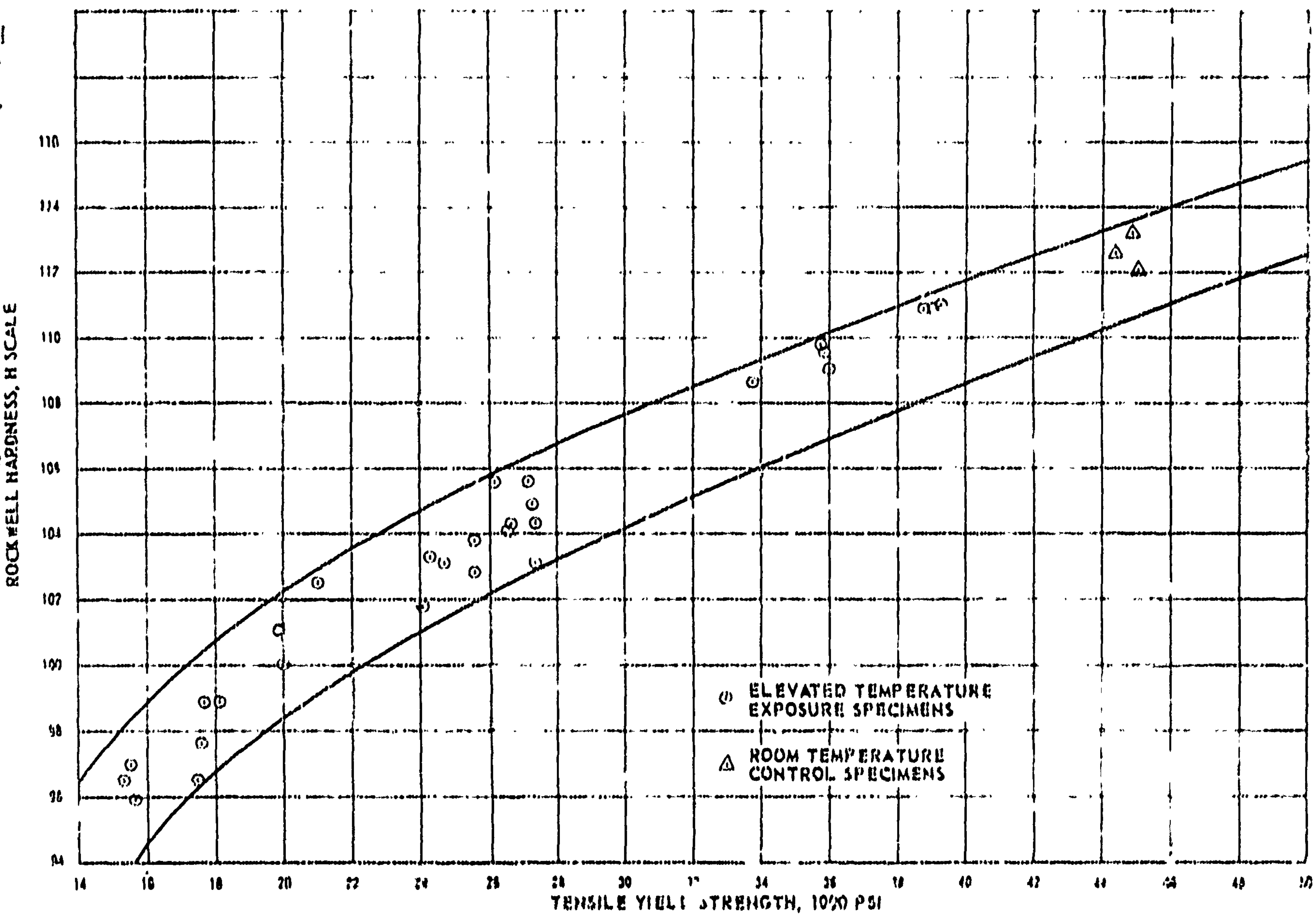

FIGURE 105 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 2024-T3 ALUMINUM ALLOY

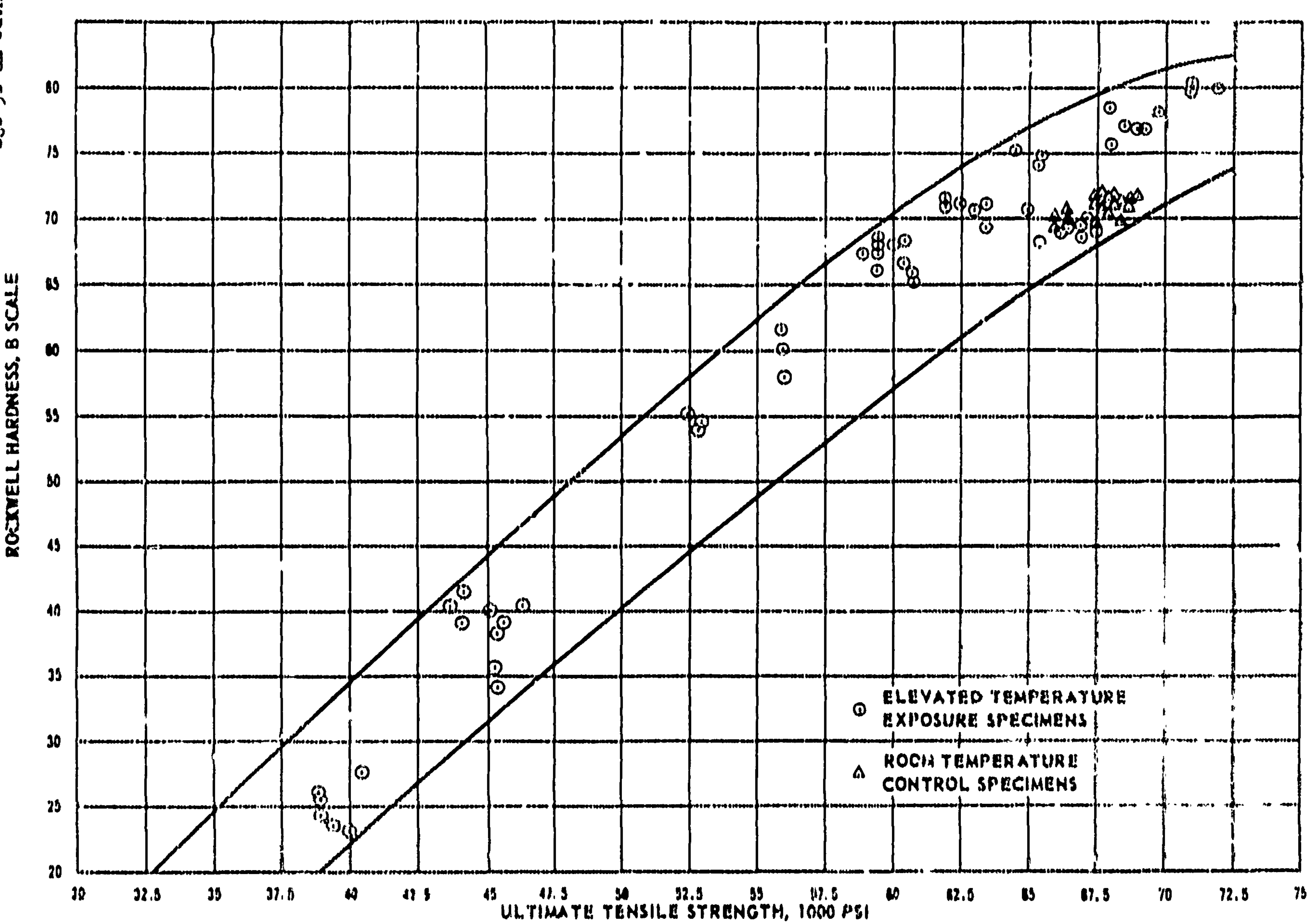

FIGURE 106 ROCKWELL B VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

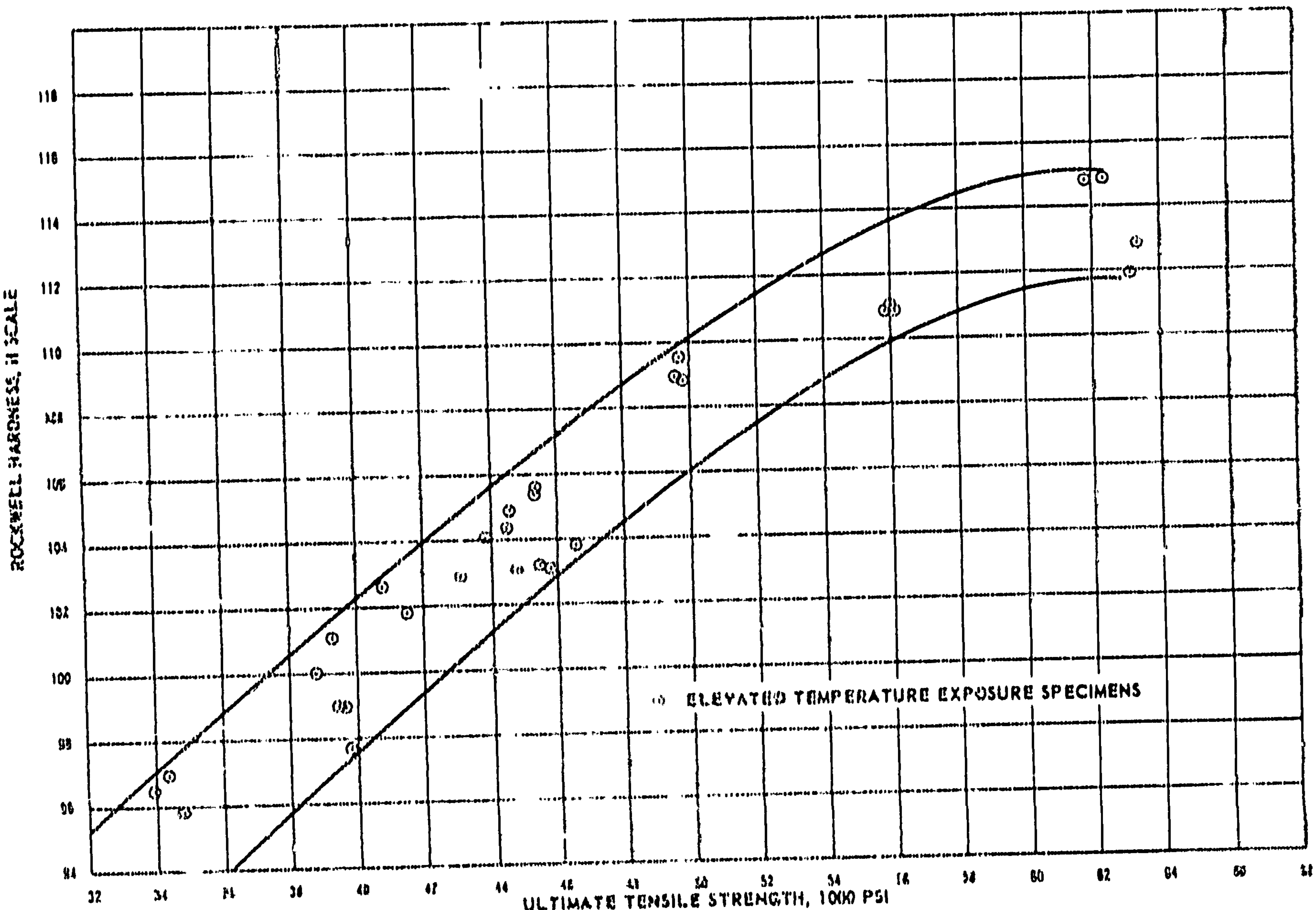

FIGURE 107 ROCKWELL H VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

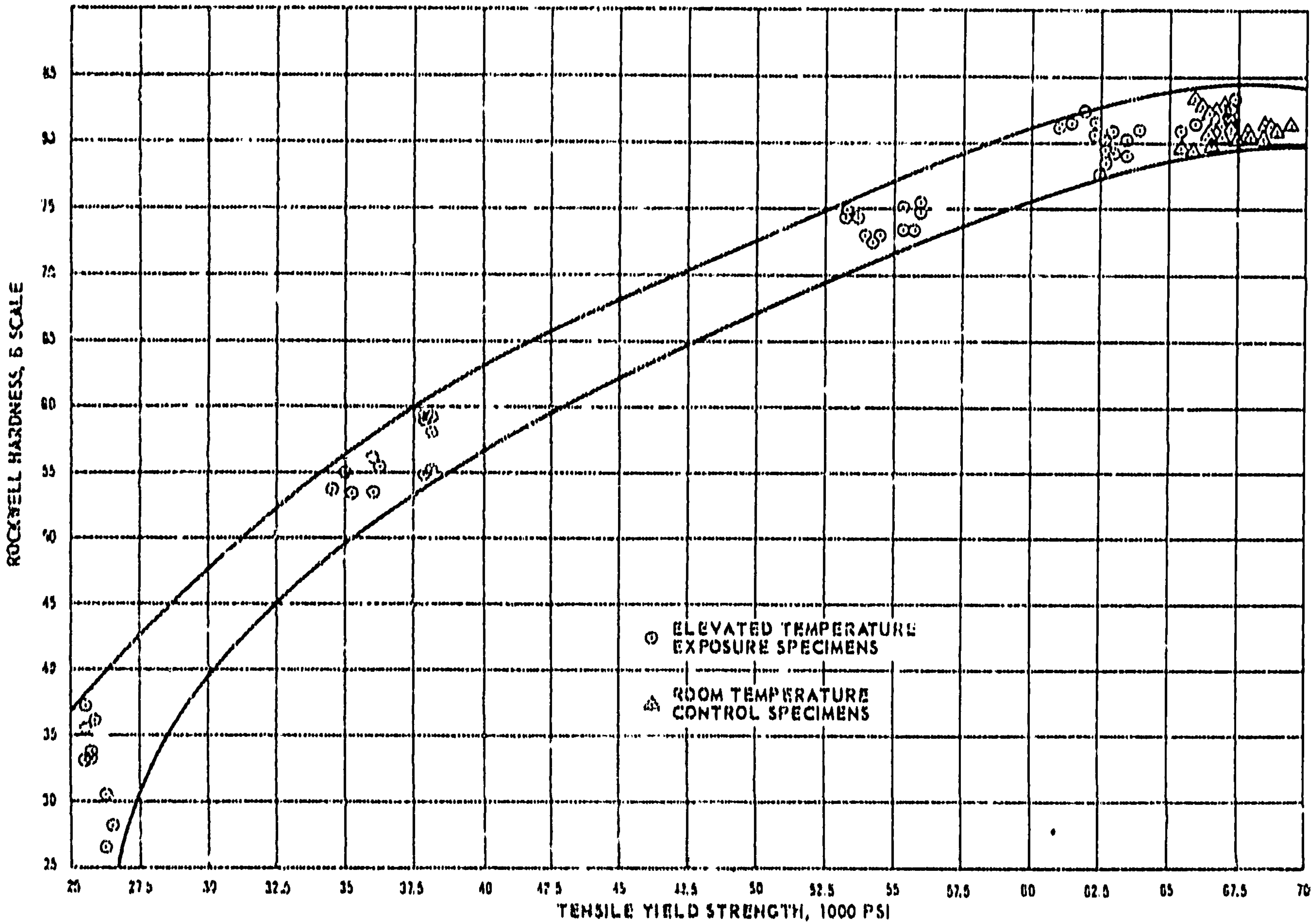

FIGURE 108 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 7075-T6 ALUMINUM ALLOY

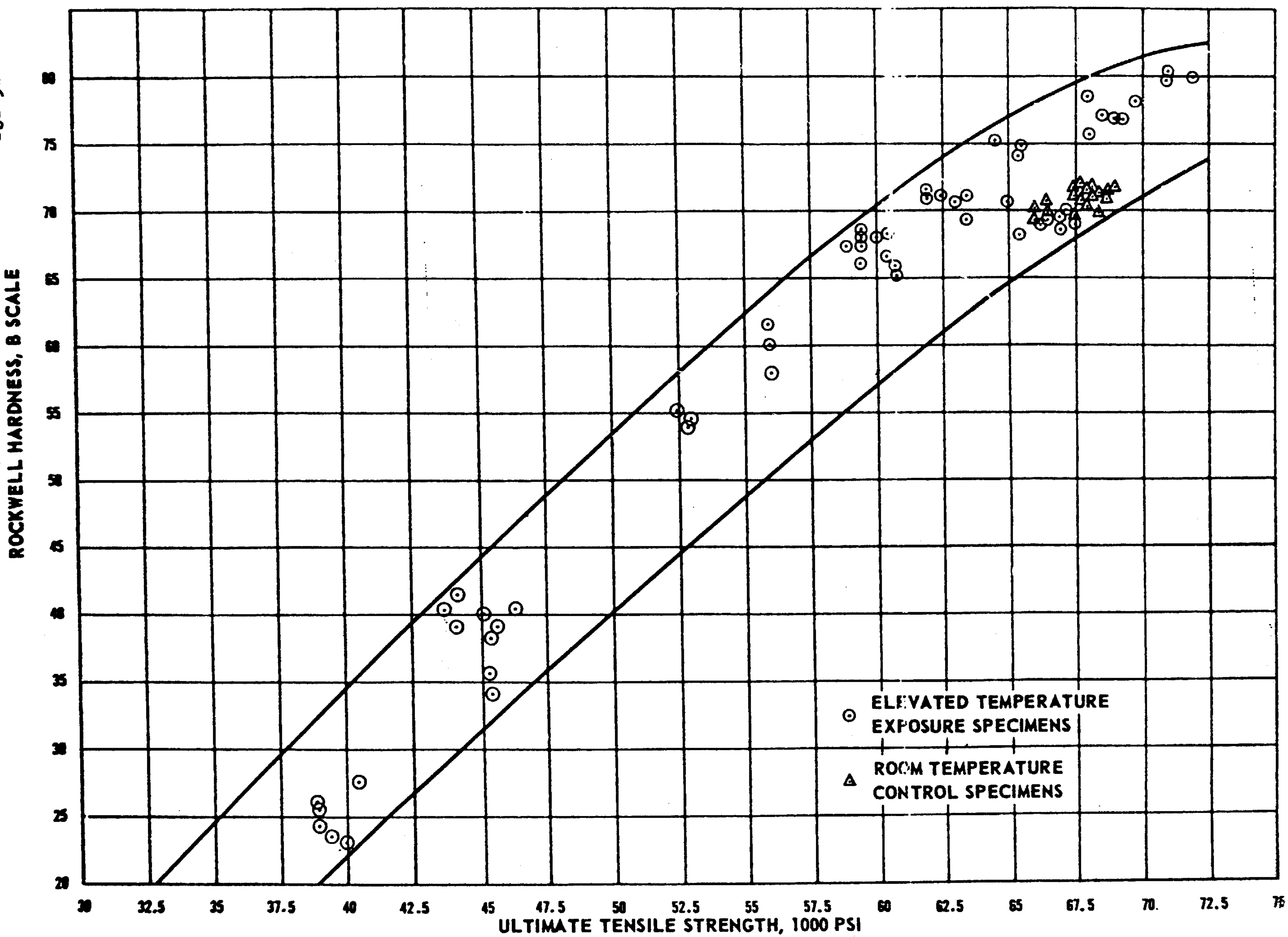

FIGURE 106 ROCKWELL B VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

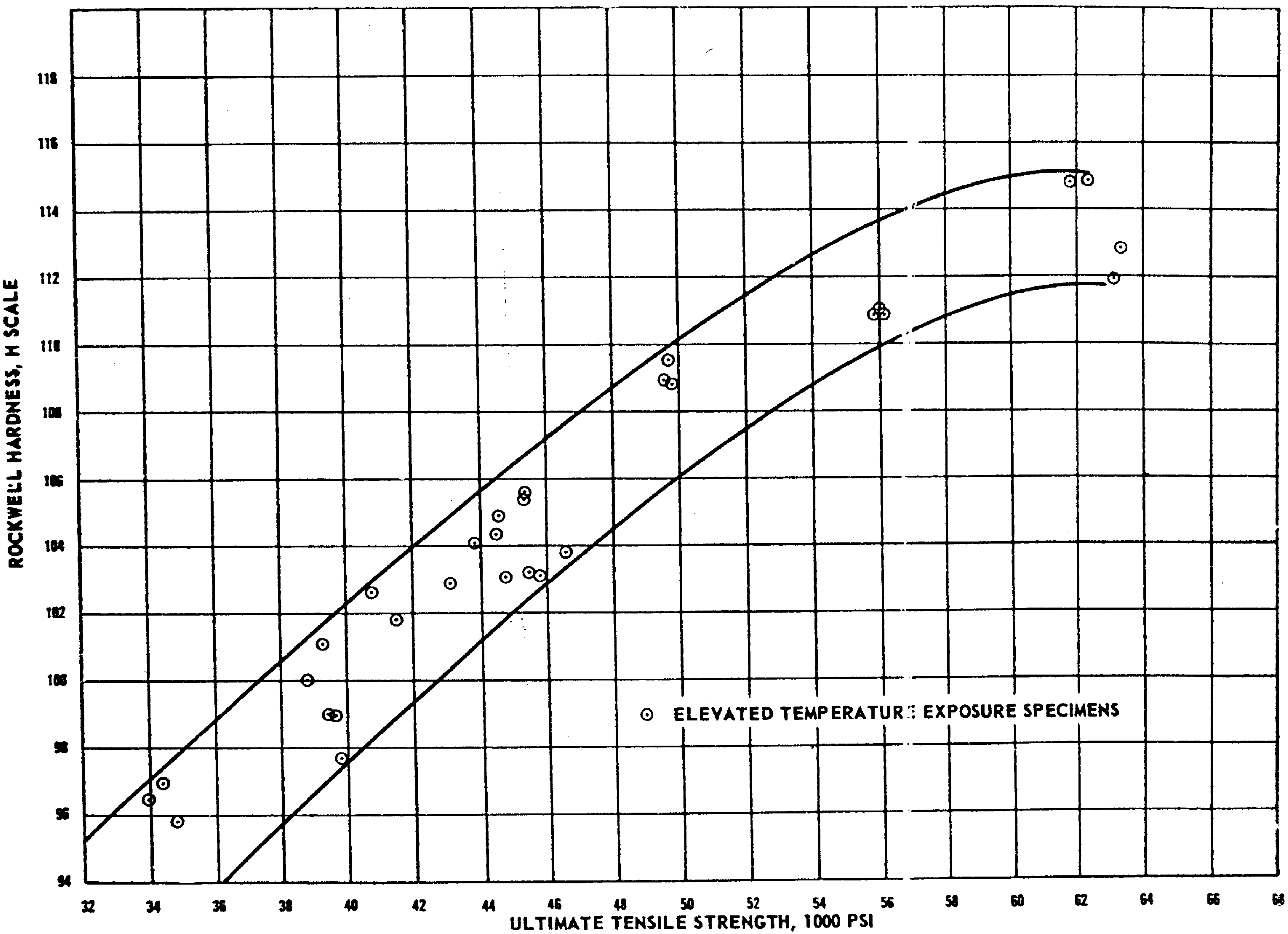

FIGURE 107 ROCKWELL H VERSUS ULTIMATE TENSILE STRENGTH FOR 2024-T3 ALUMINUM ALLOY

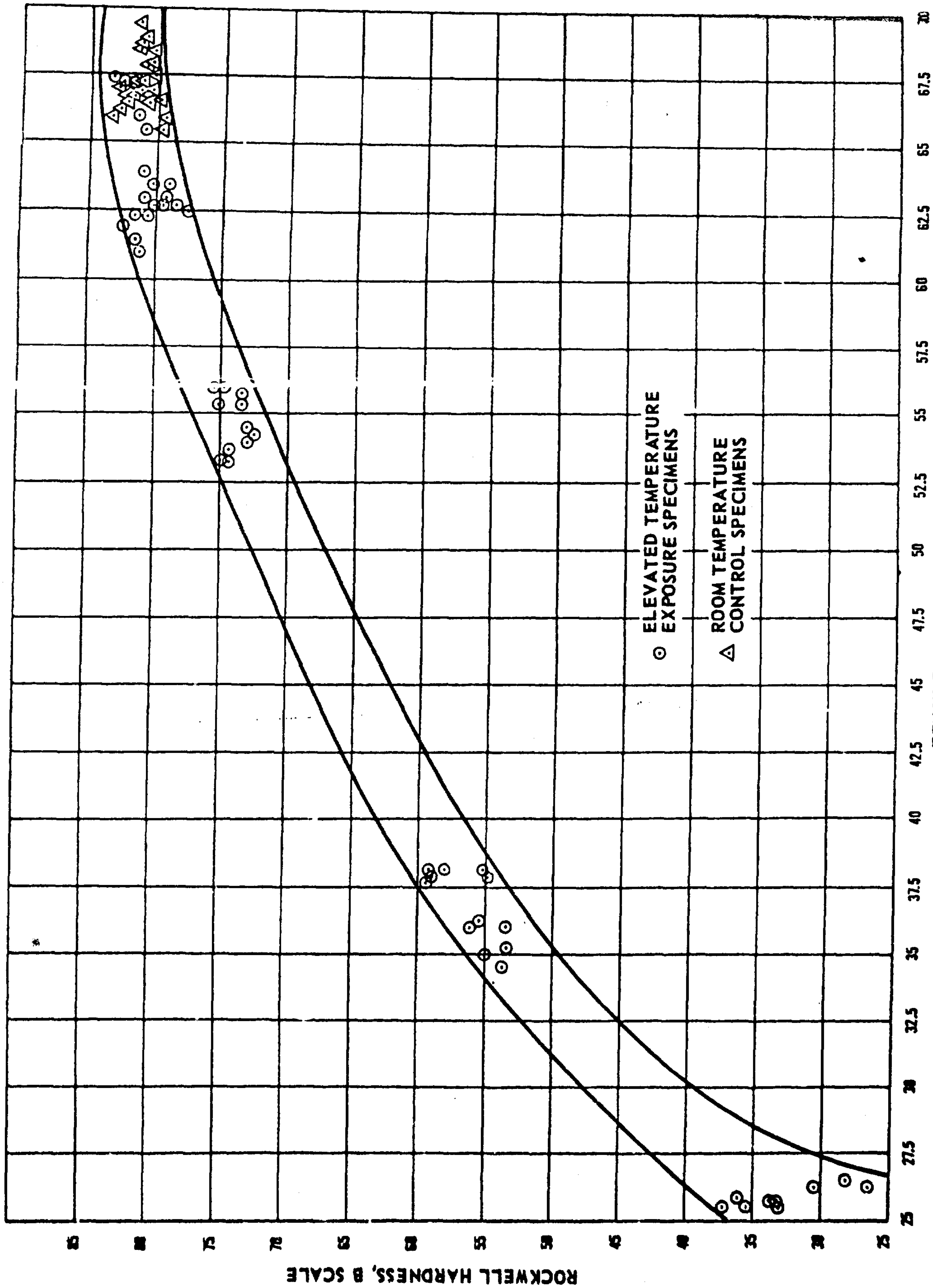

FIGURE 108 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 7075-T6 ALUMINUM ALLOY

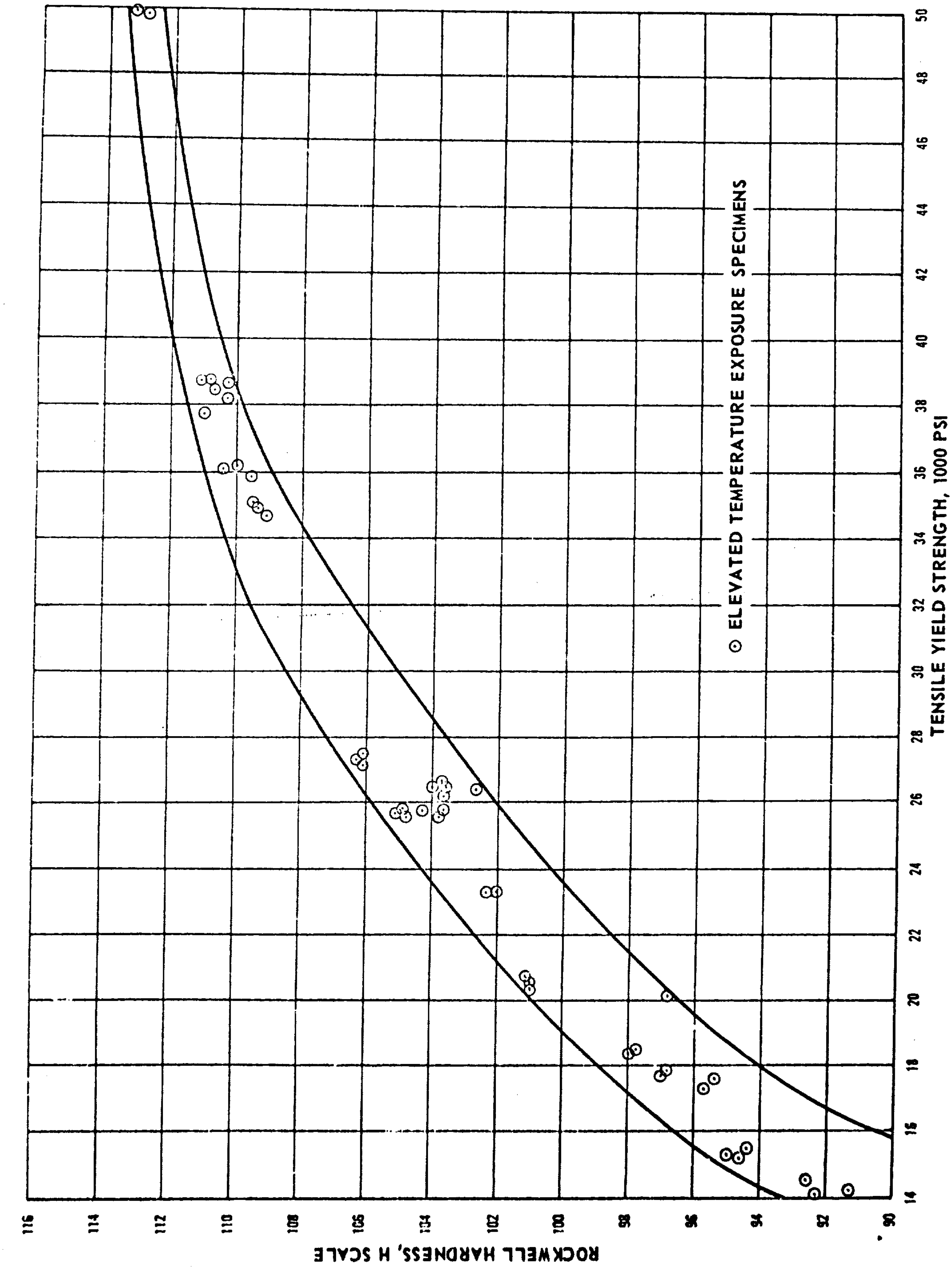

FIGURE 109 ROCKWELL HARDNESS VERSUS TENSILE YIELD STRENGTH OF 7075-T6 ALUMINUM ALLOY

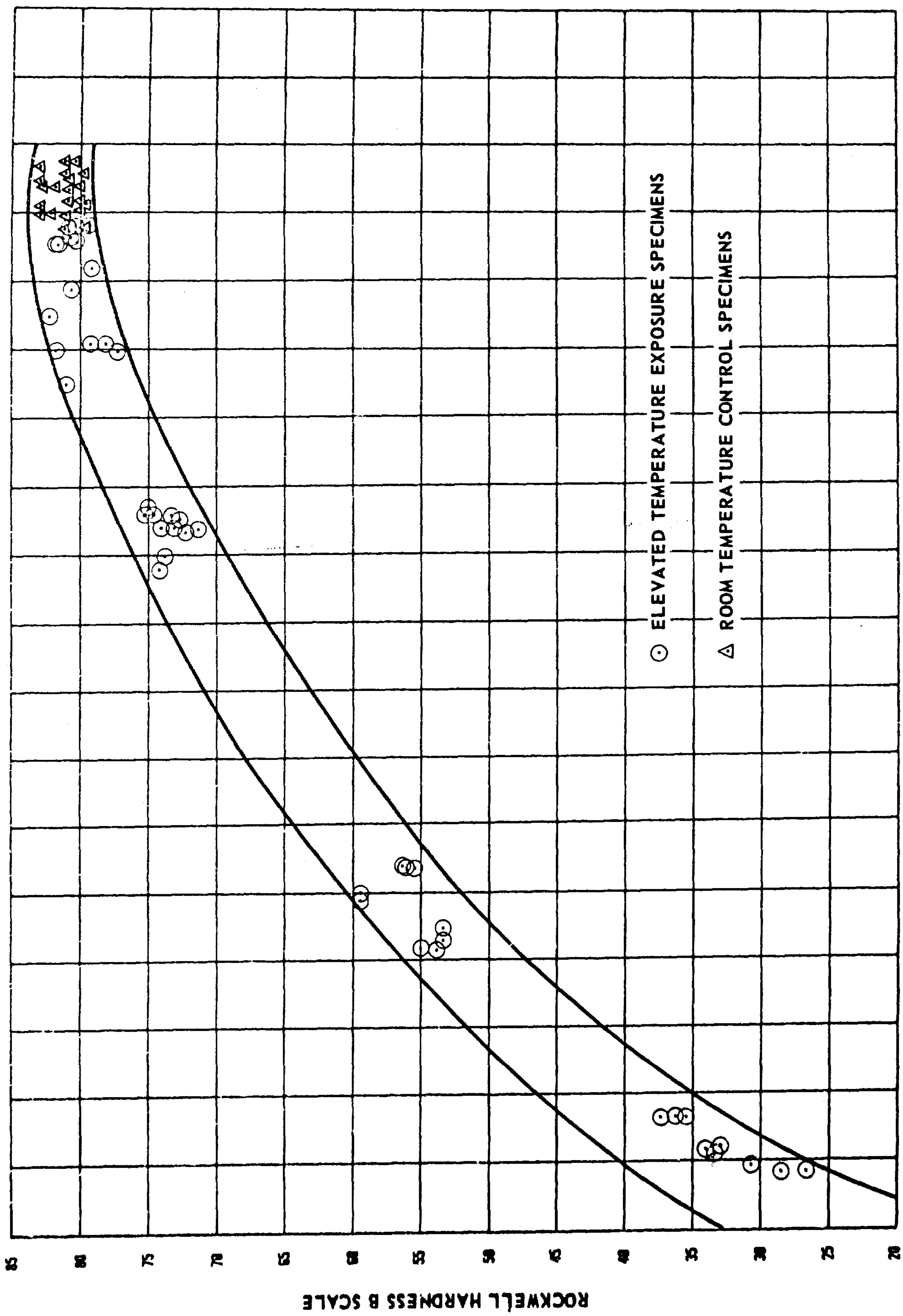

FIGURE 110 ROCKWELL B VERSUS ULTIMATE TENSILE STRENGTH FOR 7075-T6 ALUMINUM ALLOY

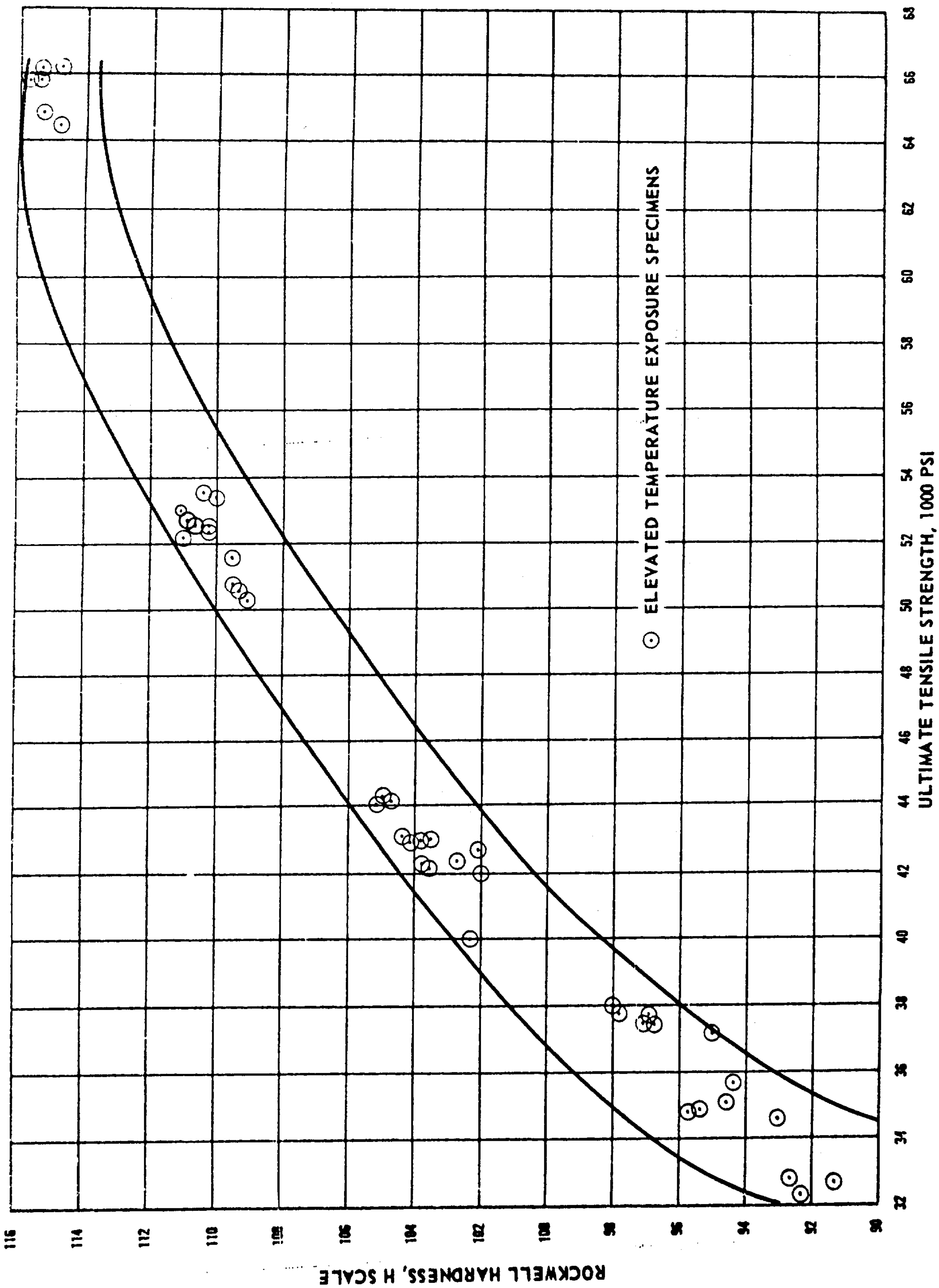

FIGURE 111 ROCKWELL H VERSUS ULTIMATE TENSILE STRENGTH FOR 7075-T6 ALUMINUM ALLOY

TABLE XXIII

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Tempera-ture °F	Exposure Time Hrs.	Testing Tempera-ture °F	Propor-tional Limit psi	Average Proportional Limit	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity	Yield Strength psi	Average Yield Strength	Ultimate Strength psi	Average Ultimate Strength	Elong. % in 2"	Ave. Elong.	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
2GG 1	-	-	200	20060		9.59		44310		63850		19.0		.0050	.069
2GG 2	-	-	200	22530	22610	9.85	9.81	43830	44220	63890	63990	19.0	19.0	.0046	.069
2GG 3	-	-	200	25250		10.00		44530		64220		19.0		.0047	.069
2GG 4	-	-	300	22990		9.46		41820		56940		22.5		.0045	.069
2GG10	-	-	300	17330	19780	9.41	9.43	41260	41540	56590	56760	22.5	23.3	.0047	.069
2GG 6	-	-	300	19020		9.41		41540		56760		25.0		.0040	.069
2GG 7	-	-	400	16310		7.41		35070		51080		15.0		.0044	.069
2GG 8	-	-	400	17690	17980	9.59	9.42	33850	34720	50920	50920	15.0	14.5	.0044	.069
2GG 9	-	-	400	19930		9.26		35230		50770		13.5		.0042	.069
2H 9	300	0.1	R.T.(1)	17190		10.34		42970		67810		18.5		.0055	.067
2H 10	300	0.1	R.T.	23750	21280	11.60	10.65	44060	43340	67190	67270	20.0	19.7	.0041	.067
2H 11	300	0.1	R.T.	22900		10.00		42990		66820		20.5		.0046	.067
2H 12	300	0.1	200	20310		10.23		41410		62970		19.0		.0047	.067
2I 2	300	0.1	200	17240	18210	10.25	10.32	38870	40300	63010	62610	20.0	20.2	.0052	.067
2J 3	300	0.1	200	17080		10.47		40620		61850		21.5		.0050	.067
2I 3	300	0.1	300	18650		10.18		39810		57370		24.0		.0051	.067
2I 4	300	0.1	300	18080	17640	10.21	10.17	40000	39970	57550	57490	24.5	23.6	.0050	.067
2I 5	300	0.1	300	16200		10.11		40090		57550		22.5		.0049	.067
2I 6	300	0.1	400	16820		9.77		35380		52520		20.0		.0050	.067
2I 7	300	0.1	400	15520	16350	9.72	9.68	35580	35320	52510	52190	20.0	19.8	.0052	.067
2J 2	300	0.1	400	16720		9.55		35000		51560		19.0		.0051	.067
2E 7	400	0.1	R.T.	15050		10.33		37930		63320		19.5		.0054	.061
2E 8	400	0.1	R.T.	15720	14500	10.53	10.47	38050	38010	63370	63400	21.0	20.7	.0054	.061
2E 9	400	0.1	R.T.	12740		10.56		38050		63520		21.5		.0054	.061
2E 11	400	0.1	200	16410		10.08		37500		62190		23.0		.0047	.067
2E 12	400	0.1	200	16410	16420	9.98	9.94	37810	37670	62500	62440	23.0	22.8	.0050	.067
2F 7	400	0.1	200	16450		9.77		37700		62620		22.5		.0050	.067
2F 1	400	0.1	300	21090		10.50		37810		58280		23.5		.0048	.075
2F 2	400	0.1	300	26170	22720	9.32	9.86	38320	38020	58410	58400	24.0	23.5	.0061	.075
2F 3	400	0.1	300	20900		9.75		37940		58520		23.0		.0044	.075
2F 4	400	0.1	400	25700		8.22		37380		52650		19.5		.0052	.061
2F 5	400	0.1	400	25000	25520	8.44	8.27	36800	37190	52640	52700	19.0	19.0	.0054	.061
2F 6	400	0.1	400	25860		8.14		37380		52800		18.5		.0054	.061

TABLE XXIII (cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURE AT ELEVATED TEMPERATURES

2F 6	500	0.1	R.T.	(2)		(2)		(2)		62420		8.0		.0051	.075
2F 9	500	0.1	R.T.	34880	32580	9.9	10.08	50000	49540	62040	62090	8.0	8.0	.0050	.075
2F 10	500	0.1	R.T.	30280		10.26		49070		61800		8.0		.0051	.075
2T 1(3)	500	0.1	R.T.	39440	38690	9.86	9.80	55590	55600	64750	64700	8.0	7.8	.0051	.071
2T 2(3)	500	0.1	R.T.	38940		9.74		55610		64640		7.5		.0053	.071
2F 11	500	0.1	200	37540		10.00		48130		59810		9.0		.0050	.075
2G 1	500	0.1	200	36760	35530	9.37	9.78	51400	50310	59810	59850	8.5	8.7	.0053	.075
2G 2	500	0.1	200	32300		9.96		51400		59940		8.5		.0049	.075
2G 3	500	0.1	300	28190		10.28		48290		52960		12.0		.0047	.075
2G 4	500	0.1	300	34420	29300	9.56	9.88	48440	48390	53120	53120	12.0	11.8	.0047	.075
2G 5	500	0.1	300	25000		9.79		48440		53280		11.5		.0046	.075
2G 6	500	0.1	400	20000		8.94		40780		42340		12.5		.0050	.067
2G 7	500	0.1	400	20960	21260	9.38	9.57	41930	41630	43170	42980	15.5	13.8	.0051	.067
2G 8	500	0.1	400	22810		10.38		42190		43440		13.5		.0048	.067
2G 9	600	0.1	R.T.	20310		10.40		39060		56090		8.5		.0048	.067
2G 10	600	0.1	R.T.	25860	22500	9.81	10.14	39340	39090	55960	55950	8.5	8.5	.0048	.067
2G 11	600	0.1	R.T.	21320		10.22		38870		55800		8.5		.0046	.067
2G 12	600	0.1	200	26970		9.26		38330		53630		9.0		.0046	.067
2H 1	600	0.1	200	26260	26510	9.48	9.54	37580	37880	53300	53360	9.0	9.0	.0047	.067
2H 2	600	0.1	200	25310		9.88		37740		53150		9.0		.0046	.067
2H 3	600	0.1	300	19650		10.49		36640		46860		13.0		.0050	.067
2H 4	600	0.1	300	20940	21030	10.62	10.41	37190	36900	47190	47080	12.5	13.0	.0060	.067
2H 5	600	0.1	300	22500		10.12		36880		47190		13.5		.0054	.067
2H 6	600	0.1	400	19530		9.52		33590		37190		17.0		.0053	.067
2H 7	600	0.1	400	20060	19880	9.66	9.49	33490	33680	36730	37090	17.5	17.2	.0047	.067
2H 8	600	0.1	400	20060		9.29		33950		37350		17.0		.0047	.067
2C 28	400	1.0	R.T.	(2)		(2)		(2)		68280		15.5		.0045	.061
2C 29	400	1.0	R.T.	34430	35650	9.69	9.76	51730	51510	67930	68160	16.0	15.8	.0050	.061
2C 30	400	1.0	R.T.	36880		9.84		51560		68280		16.0		.0050	.061
2T 3(3)	400	1.0	R.T.	37930	40100	9.67	9.67	57120	57170	67800	67960	11.0	10.8	.0053	.071
2T 4(3)	400	1.0	R.T.	42260		9.67		57210		68110		10.5		.0053	.071
2B 17	400	1.0	200	38440		9.08		52340		65000		15.5		.0020	.022
2B 18	400	1.0	200	37240	38280	9.22	9.14	53610	53180	65200	65390	15.5	15.3	.0020	.022
2B 19	400	1.0	200	39180		9.12		53610		65990		15.0		.0020	.022
2B 20	400	1.0	300	40160		8.06		51250		60000		16.0		.0060	.075
2B 21	400	1.0	300	36610	37760	8.23	8.20	49100	48850	59840	59770	19.5	17.3	.0064	.075
2B 22	400	1.0	300	36610		8.31		49200		59470		16.5		.0069	.075
2C 25	400	1.0	400	(2)		(2)		(2)		52720		12.0		.0045	.054
2C 26	400	1.0	400	(2)	27850	(2)	8.45	(2)	47630	52050	52270	11.0	11.6	.0050	.054
2C 27	400	1.0	400	27850		8.45		47630		52270		11.6		.0048	.054
2T 8(3)	400	1.0	400	31270		10.33		48760		51080		10.0		.0051	.069
2T 9(3)	400	1.0	400	33700	32150	10.29	9.67	48760	48660	50930	50820	10.0	10.0	.0051	.069
2T 10(3)	400	1.0	400	31480		8.41		48460		50460		10.0		.0050	.069
2C 31	500	1.0	R.T.	32490		9.61		46850		60410		8.5		.0064	.061
2C 32	500	1.0	R.T.	34430	31960	9.31	9.58	46860	46950	60380	60410	7.5	7.83	.0075	.061
2C 33	500	1.0	R.T.	28960		9.82		47150		60440		7.5		.0074	.061

TABLE XXIII (Cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 0.1 AND 1.0 HOUR EXPOSURE AT ELEVATED TEMPERATURES

2C	34	500	1.0	200	29590		9.47		45570		56170		9.0		.0092	.054
2C	35	500	1.0	200	29680	29530	9.62	9.64	45710	45410	56510	56270	8.5	8.8	.0075	.054
2C	36	500	1.0	200	29340		9.85		44950		56150		9.0		.0075	.054
2D	1	500	1.0	300	25870		9.22		42590		48270		14.5		.0060	.043
2D	2	500	1.0	300	29000	27730	8.95	9.01	42790	42800	48430	48420	14.5	13.3	.0060	.043
2D	3	500	1.0	300	28320		8.88		43040		48580		11.0		.0060	.043
2D	4	500	1.0	400	22800		9.06		37420		39310		14.5		.0060	.038
2D	5	500	1.0	400	15310	18480	9.00	9.05	37190	37380	39060	39210	16.0	14.6	.0062	.038
2D	6	500	1.0	400	17350		9.10		37540		39270		13.5		.0056	.038
2D	7	600	1.0	R.T.	15310		9.63		25630		46560		9.0		.0054	.054
2D	8	600	1.0	R.T.	13790	13780	9.80	9.74	24760	24890	45770	45920	9.5	9.2	.0050	.054
2D	9	600	1.0	R.T.	12230		9.80		24290		45450		9.0		.0050	.054
2D	10	600	1.0	200	17390		8.68		24840		45340		10.0		.0061	.054
2D	11	600	1.0	200	14870	15500	8.77	8.82	25160	24760	45730	45400	9.5	9.8	.0068	.054
2D	12	600	1.0	200	14260		9.02		24290		45140		10.0		.0053	.054
2E	1	600	1.0	300	15530		8.68		24530		39750		15.5		.0053	.054
2E	2	600	1.0	300	14130	14020	8.96	9.00	24070	24060	39600	39650	16.0	16.1	.0053	.054
2E	3	600	1.0	300	12420		9.36		23600		39600		17.0		.0053	.054
2E	4	600	1.0	400	14490		8.20		22120		28190		21.5		.0054	.054
2E	5	600	1.0	400	12660	14070	8.48	8.38	21880	21980	27810	28170	21.0	20.8	.0053	.054
2E	6	600	1.0	400	15050		8.46		21940		28530		20.0		.0048	.054

(1) R.T. designates room temperature. Actual temperature was not measured but is known to be in the range 60-85°F.

(2) Autographic strain recorder curve was unsatisfactory for determining subject properties.

(3) Retest specimens to fulfill requirement of at least three good specimens per testing condition.

TABLE XXIV

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 10.0 AND 100.0 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time Hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong.	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
2L 4	400	10.0	R.T.(1)	27170		10.42		56830		65530		7.0		.0050	.081
2L 5	400	10.0	R.T.	23290	25260	10.65	10.51	56680	56590	65530	65480	7.5	7.3	.0051	.081
2L 6	400	10.0	R.T.	25310		10.45		56270		65370		7.5		.0051	.081
2L 7	400	10.0	200	31690		9.37		52620		59230		9.0		.0053	.075
2L 8	400	10.0	200	33180	32530	9.94	9.56	53090	52880	59410	59340	9.5	9.3	.0050	.075
2L 9	400	10.0	200	32710		9.41		52920		59380		9.5		.0054	.075
2L 10	400	10.0	300	29780		9.73		49230		52010		13.0		.0039	.075
2L 11	400	10.0	300	21140	25070	9.62	9.59	48610	48610	51700	51650	12.5	12.7	.0046	.075
2L 12	400	10.0	300	24300		9.44		47990		51240		12.5		.0048	.075
2K 1	400	10.0	400	20000		9.38		43380		44460		11.5		.0045	.075
2K 2	400	10.0	400	20550	20210	9.39	9.37	43100	43240	44170	44370	13.0	12.0	.0046	.075
2K 3	400	10.0	400	20090		9.36		43250		44480		11.5		.0050	.075
2K 4	500	10.0	R.T.(1)	21230		9.92		36010		52830		8.5		.0036	.054
2K 5	500	10.0	R.T.	20000	19970	10.12	10.14	35940	35930	52810	52760	9.0	8.7	.0037	.054
2K 6	500	10.0	R.T.	18690		10.37		35830		52650		8.5		.0036	.054
2K 7	500	10.0	200	20340		9.48		35250		48760		8.0		.0036	.061
2K 8	500	10.0	200	20650	20260	10.49	9.82	35250	35230	48760	48810	8.0	8.5	.0035	.061
2K 9	500	10.0	200	19780		9.50		35200		48910		9.5		.0037	.061
2K 10	500	10.0	300	17860		9.54		33540		41300		15.0		.0048	.067
2K 11	500	10.0	300	19630	18450	8.93	9.10	33860	33850	41120	41240	15.0	15.5	.0048	.067
2K 12	500	10.0	300	17860		8.84		34160		41300		16.5		.0047	.067
2L 1	500	10.0	400	14350		8.81		29500		32140		16.5		.0049	.075
2L 2	500	10.0	400	17190	15980	8.54	8.78	29530	29360	32340	32170	17.0	16.8	.0050	.075
2L 3	500	10.0	400	16410		9.01		29060		32030		17.0		.0048	.075
2J 1	600	10.0	R.T.(1)	8333		10.06		18120		39660		11.5		.0064	.067
2J 2	500	10.0	R.T.	9231	8560	9.33	9.70	17690	17800	39380	39620	11.5	12.0	.0061	.067
2J 3	600	10.0	R.T.	8117		9.73		17590		39820		13.0		.0061	.067
2J 7	600	10.0	200	9875		10.36		18530		40470	11.01	11.0		.0051	.067
2J 8	500	10.0	200	8916	9284	10.81	10.46	18420	18460	40400	40390	10.5	10.8	.0052	.067
2J 9	600	10.0	200	9062		10.21		18440		40310		11.0		.0051	.067
2J 10	600	10.0	300	11250		10.42		18440		34840		20.0		.0043	.054
2J 11	600	10.0	300	9467	10150	10.13	10.42	17870	18070	34800	34860	21.0	20.6	.0045	.054
2J 12	600	10.0	300	9737		10.70		17900		34950		21.0		.0048	.054

TABLE XXIV (Cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 10.0 AND 100.0 HOURS EXPOSURE AT ELEVATED TEMPERATURES

2K 1	600	10.0	400	10600		8.62		17020		25860		24.0		.0050	.054
2K 2	600	10.0	400	10900	10600	8.84	8.82	16970	16840	25620	25550	24.0	24.0	.0045	.054
2K 3	600	10.0	400	10100		9.01		16650		25170		24.0		.0046	.054
2P 6	300	100.0	R.T.	42100		9.14		59820		71170		12.5		.0050	.086
2P 7	300	100.0	R.T.	44500	42740	8.93	9.09	59630	59560	70950	70960	12.5	12.5	.0048	.086
2P 8	300	100.0	R.T.	41500		9.22		59230		70770		12.5		.0051	.086
2P 9	300	100.0	200	36200		9.52		57100		67280		13.0		.0050	.081
2P 10	300	100.0	200	39800	38450	9.24	9.31	57230	57140	67080	67150	14.5	13.5	.0049	.081
2P 11	300	100.0	200	39200		9.18		57080		67080		13.0		.0048	.081
2P 12	300	100.0	300	35500		9.28		54080		61040		14.0		.0049	.081
2Q 1	300	100.0	300	36800	34670	8.93	9.15	53830	53860	60500	60790	15.0	14.2	.0051	.081
2Q 2	300	100.0	300	31600		9.20		53680		60740		13.5		.0050	.081
2Q 3	300	100.0	400	34700		8.08		48460		52310		11.5		.0050	.081
2Q 4	300	100.0	400	34500	35620	8.66	8.26	48420	48780	52450	52410	12.5	12.0	.0049	.081
2Q 5	300	100.0	400	37200		8.05		49000		52450		12.0		.0050	.081
2M 5	400	101.0(3)	R.T.	30300		9.03		46990		59440		8.0		.0055	.067
2M 6	400	101.0(3)	R.T.	25200	27140	10.00	9.09	46630	46720	59360	59440	9.0	8.2	.0055	.067
2M 7	400	101.0(3)	R.T.	26000		9.03		46930		59510		7.5		.0057	.067
2M 8	400	101.0(3)	200	21600		9.32		45260		54740		10.0		.0049	.081
2M 9	400	101.0(3)	200	19600	20890	9.10	9.20	45240	45090	54290	54500	10.5	10.2	.0051	.081
2M 10	400	101.0(3)	200	22300		9.18		44770		54460		10.0		.0050	.081
2M 11	400	101.0(3)	300	27600		9.20		41410		46930		12.0		.0048	.081
2M 12	400	101.0(3)	300	26300	26540	8.65	8.65	41780	41720	46780	46930	10.5	11.7	.0046	.081
2O 1	400	101.0(3)	300	25400		8.10		41980		47070		12.5		.0048	.081
2O 2	400	101.0(3)	400	19400		8.75		36810		39110		15.5		.0050	.086
2O 3	400	101.0(3)	400	21000	20930	8.19	8.40	36810	36690	39110	39050	13.5	13.8	.0050	.086
2O 4	400	101.0(3)	400	22300		8.52		36460		38920		12.5		.0050	.086
2N 4	500	100.0	R.T.	11600		9.90		21010		40640		10.0		.0043	.081
2N 5	500	100.0	R.T.	11000	10910	10.57	10.20	20060	20340	38740	39350	10.0	10.0	.0040	.081
2N 6	500	100.0	R.T.	9782		10.14		19940		39260		10.0		.0043	.081
2N 8	500	100.0	200	11400		9.16		19850		37150		11.5		.0053	.086
2N 9	500	100.0	200	13300	11490	7.09	8.89	19050	19310	36500	36820	12.5	12.7	.0056	.086
2N 10	500	100.0	200	9016		10.42		19020		36770		14.0		.0055	.086
2N 11	500	100.0	300	10110		9.40		18740		30920		22.0		.0022	.086
2N 12	500	100.0	300	11600	10690	9.48	9.50	19100	18560	31020	30750	20.0	20.8	.0025	.086
2N 1	500	100.0	300	10310		9.53		17850		30310		20.5		.0021	.086
2N 2	500	100.0	400	(2)		(2)		(2)		21800		34.5		.0024	.086
2N 3	500	100.0	400	11180	10450	8.14	8.54	16810	16870	26050	22990	31.0	30.6	.0020	.086
2N 4	500	100.0	400	9530		8.90		16550		21570		30.0		.0025	.086
2N 13	500	100.0	400	10000		8.60		17250		22470		27.0		.0026	.086

NOTE: (1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.
(2) Autographic recorder curve was unsatisfactory for determining subject properties.
(3) Due to testing emergency, test was delayed one hour.

TABLE XXV

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 1000 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time Hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong.	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
22 1	300	1000.0	R.T.(1)	38460		9.59		61540		68920		8.0		.0055	.081
22 2	300	1000.0	R.T.	38700	38510	9.55	9.79	61460	61630	69350	69320	7.5	7.7	.0058	.081
22 3	300	1000.0	R.T.	39380		10.23		61880		69650		7.5		.0057	.081
22 4	300	1000.0	200	39480		9.26		57360		62580		8.0		.0054	.081
22 5	300	1000.0	200	35360	34860	9.35	9.36	57450	57380	62610	62610	8.0	8.0	.0056	.081
22 6	300	1000.0	200	29730		9.98		57320		62650		8.0		.0056	.081
22 7	300	1000.0	300	23320		9.72		52590		55340		10.5		.0053	.081
22 8	300	1000.0	300	29140	25770	9.15	9.49	52910	52750	55210	55200	10.5	10.7	.0056	.081
22 9	300	1000.0	300	24850		9.59		52760		55060		11.0		.0057	.081
22 10	300	1000.0	400	21010		9.20		45410		46180		13.0		.0049	.069
22 11	300	1000.0	400	26150	23670	9.00	9.06	45690	45620	46310	46320	11.5	12.2	.0051	.069
22 12	300	1000.0	400	23850		8.97		45750		46460		12.0		.0050	.069
27 1	400	1000.0	R.T.	21230		9.79		33790		49850		9.5		.0049	.081
27 2	400	1000.0	R.T.	(2)	21230	(2)	9.79	(2)	33790	49540	49690	8.5	8.8	.0046	.081
27 3	400	1000.0	R.T.	(2)		(2)		(2)		49690		8.5		.0048	.081
27 4	400	1000.0	200	16110		9.81		32220		44230		9.0		.0045	.071
27 5	400	1000.0	200	11430	12970	10.35	9.92	31400	32150	44060	44530	9.5	9.2	.0046	.071
27 6	400	1000.0	200	11370		9.61		32830		45290		9.0		.0048	.071
27 7	400	1000.0	300	13760		9.59		31040		38530		15.5		.0043	.081
27 8	400	1000.0	300	13860	13820	9.93	9.56	31940	31300	39200	38630	11.0	12.5	.0043	.081
27 9	400	1000.0	300	13850		9.17		30920		38150		11.0		.0048	.081
27 10	400	1000.0	400	13190		9.83		27700		31600		13.0		.0050	.081
27 11	400	1000.0	400	13930	13550	9.93	10.28	27650	27920	31730	31930	13.0	13.8	.0048	.081
27 12	400	1000.0	400	13540		11.10		28400		32460		15.5		.0048	.081
24 1	500	1000.0	R.T.	6860		9.49		15380		33860		12.5		.0044	.075
24 2	500	1000.0	R.T.	7320	7420	11.16	10.11	15670	15540	34710	34340	11.5	12.5	.0046	.075
24 3	500	1000.0	R.T.	8090		9.67		15560		34440		13.5		.0050	.075
24 4	500	1000.0	200	9490		9.07		15250		32440		15.0		.0045	.075
24 5	500	1000.0	200	9520	9490	8.23	8.71	15620	15420	32540	32500	15.0	14.7	.0045	.075
24 6	500	1000.0	200	9450		8.82		15400		32540		14.0		.0035	.075
24 7	500	1000.0	300	8010		10.08		14300		26190		27.0		.0044	.075
24 8	500	1000.0	300	7940	7511	9.85	10.96	14580	14660	26470	26630	32.0	27.0	.0026	.075
24 10	500	1000.0	300	6570		12.96		15100		[illegible]		22.0		.0023	.075
24 11	500	1000.0	400	6450		11.07		13890		19650		27.0		.0025	.075
24 12	500	1000.0	400	6120	6070	11.12	11.10	13400	13360	19210	18850	28.5	33.8	.0025	.075
24 13	500	1000.0	400	5640		11.11		12790		17690		46.0		.0026	.075

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60 - 85° F.

(2) Autographic strain recorder curve was unsatisfactory for determining subject properties.

TABLE XXVI

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen No.	Sequential Exposure Time & Temp. First 1.0 Hr. °F	Second 10 Hrs. °F	Third 100 Hrs. °F	Fourth 1000 Hrs. °F	Testing Temp. °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6psi	Average Modulus of Elasticity 10^6psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong. % in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
2A 1	500	400	-	-	R.T.(1)	21030		10.50		46260		59500		8.0		.0054	.054
2A 2	500	400	-	-	R.T.	20400	23160	10.43	10.41	46570	46830	59500	59710	7.5	7.8	.0054	.054
2A 3	500	400	-	-	R.T.	28040		10.31		47660		60120		8.0		.0053	.054
2A 4	500	400	-	-	200	28500		9.88		45950		55140		10.0		.0057	.054
2A 5	500	400	-	-	200	31330	30760	9.09	9.32	45670	45810	54000	54970	9.5	9.8	.0062	.054
2A 6	500	400	-	-	200	32450		8.99		45810		54970		10.0		.0064	.054
2A 7	500	400	-	-	300	28000		9.42		42310		46920		16.0		.0057	.050
2A 8	500	400	-	-	300	28140	28160	9.28	9.42	42660	42350	47400	46990	13.5	14.1	.0058	.050
2A 9	500	400	-	-	300	28350		9.55		42070		46650		13.0		.0058	.050
2A 10	500	400	-	-	400	23450		8.70		37230		39540		13.5		.0058	.050
2A 11	500	400	-	-	400	21010	23100	9.30	8.90	37120	37160	39420	39360	15.5	14.0	.0057	.050
2A 12	500	400	-	-	400	24850		8.67		37120		39110		13.0		.0058	.050
2I 1	500	400	300	-	R.T.	23990		10.79		46900		59440		9.5		.0036	.054
2I 2	500	400	300	-	R.T.	28790	27780	10.24	10.43	47830	47780	59910	59950	9.0	9.0	.0035	.054
2I 3	500	400	300	-	R.T.	30560		10.25		48610		60490		8.5		.0035	.054
2I 4	500	400	300	-	200	32970		9.49		46900		55260		10.0		.0045	.067
2I 5	500	400	300	-	200	30220	31870	9.84	9.56	46170	46460	54600	54880	10.0	10.0	.0044	.067
2I 6	500	400	300	-	200	32410		9.36		46300		54780		10.0		.0045	.067
2I 7	500	400	300	-	300	23850		9.71		42000		46770		12.5		.0047	.067
2I 8	500	400	300	-	300	27150	25020	9.73	9.61	42180	41670	46930	46570	13.5	13.0	.0055	.067
2I 9	500	400	300	-	300	24070		9.35		40830		46020		13.0		.0055	.067
2I 10	500	400	300	-	400	65690		8.29		36700		38680		15.5		.0057	.067
2I 11	500	400	300	-	400	25310	38560	8.42	8.43	36200	36420	38500	38710	17.0	15.5	.0058	.067
2I 12	500	400	300	-	400	24690		8.57		36350		38960		14.0		.0060	.067
2AA 1	600	500	-	-	R.T.	15430		9.00		27160		45370		8.5		.0057	.071
2AA 2	600	500	-	-	R.T.	14950	15040	10.75	9.83	26700	26680	45170	45280	8.5	8.8	.0047	.061
2AA 3	600	500	-	-	R.T.	14730		9.17		26180		45300		9.5		.0045	.061
2AA 4	600	500	-	-	200	17080		9.32		25160		42080		10.0		.0043	.061
2AA 5	600	500	-	-	200	15310	15480	9.61	9.50	25130	25020	42500	42230	10.0	10.2	.0043	.061
2AA 6	600	500	-	-	200	14060		9.57		24770		42110		10.5		.0050	.061
2AA 7	600	500	-	-	300	15110		9.42		23990		34890		13.5		.0044	.061
2AA 8	600	500	-	-	300	11290	13520	9.64	9.37	23200	23770	34330	34690	14.5	14.0	.0050	.061
2AA 9	600	500	-	-	300	14160		9.06		24130		34840		14.0		.0043	.061
2AA10	600	500	-	-	400	12580		8.65		21540		26100		21.0		.0044	.061
2AA11	600	500	-	-	400	11430	11520	8.73	8.74	21750	21680	26350	26230	16.0	18.0	.0044	.061
2AA12	600	500	-	-	400	10560		8.85		21740		26240		17.0		.0043	.061

TABLE XXVI (Cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

2BB 1	600	500	400	-	R.T.	16460		9.69		27430		44670		9.5		.0049	.069
2BB 2	600	500	400	-	R.T.	16190	15600	9.60	9.78	25690	25760	43080	43090	10.5	10.2	.0050	.069
2BB 3	600	500	400	-	R.T.	14140		10.05		24140		41510		10.5		.0050	.069
2BB 4	600	500	400	-	200	10030		10.93		23560		38240		12.0		.0049	.069
2BB 5	600	500	400	-	200	13920	12450	9.68	10.17	23330	23380	37960	37990	11.5	11.5	.0051	.069
2BB 6	600	500	400	-	200	13400		9.91		23250		37770		11.0		.0051	.069
2BB 7	600	500	400	-	300	11720		9.79		23040		32360		14.5		.0053	.069
2BB 8	600	500	400	-	300	10020	10330	11.63	11.05	23280	22560	32820	32100	15.5	17.0	.0048	.069
2BB 9	600	500	400	-	300	9230		11.73		21360		31120		21.0		.0048	.069
2BB10	600	500	400	-	400	11300		9.57		20740		25540		21.0		.0045	.069
2BB11	600	500	400	-	400	9780	11210	10.06	9.76	20960	21190	25780	[illegible]	15.0	17.9	.0045	.069
2BB12	600	500	400	-	400	12550		9.66		21860		26520		[illegible]		.0045	.069
2CC 1	600	500	400	300	R.T.	14460		9.60		27390		44190		10.5		[illegible]	.061
2CC 2	600	500	400	300	R.T.	7030	9670	10.00	9.62	27280	27100	44340	44090	11.0	10.8	[illegible]	.061
2CC 3	600	500	400	300	R.T.	7530		9.27		26630		43750		11.0		.0042	.061
2CC 4	600	500	400	300	200	11410		10.34		25380		38910		13.0		.0040	.061
2CC 5	600	500	400	300	200	11220	12440	8.52	9.56	25140	25250	38790	38590	13.0	13.0	.0054	.061
2CC 6	600	500	400	300	200	14690		9.81		25220		38060		13.0		.0038	.061
2CC 7	600	500	400	300	300	16040		9.58		24920		34060		15.5		.0050	.061
2CC 8	600	500	400	300	300	15220	15510	8.77	8.96	23910	24270	33080	33410	18.0	16.5	.0043	.061
2CC 9	600	500	400	300	300	15280		8.54		23980		33080		16.0		.0040	.061
2CC10	600	500	400	300	400	11590		9.10		23540		27260		19.5		.0044	.061
2CC11	600	500	400	300	400	14240	[illegible]	8.92	8.94	21580	22220	26550	26900	14.0	16.7	.0038	.061
2CC12	600	500	400	300	400	11620		8.79		21530		26890		16.5		.0048	.061

(1) RT designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

TABLE XXVII

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen Number	Sequential Exposure Time and Temperature First	Second	Third	Fourth	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity X 10^6 psi	Average Modulus of Elasticity X 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Avg. Elong.	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
	1.0 Hr.	5.0 Hrs.	30.0 Hrs.	219 Hrs.													
2JJ 1	465°F	420°F	375°F	330°F	R.T.(1)	35000		10.31		56720		67500		7.5		.0051	.064
2JJ 2	465	420	375	330	R.T.	38120	35690	10.00	10.01	55630	55990	66720	67070	7.5	7.7	.0050	.066
2JJ 3	465	420	375	330	R.T.	33960		9.71		55610		66980		8.0		.0048	.065
2JJ 4	465	420	375	330	200	29530		10.31		52500		60470		9.5		.0050	.072
2JJ 5	465	420	375	330	200	28340	29060	9.65	9.95	52340	52280	60280	60210	10.0	9.7	.0050	.068
2JJ 6	465	420	375	330	200	29320		9.90		52010		59880		9.5		.0052	.060
2JJ 7	465	420	375	330	300	26390		9.49		47840		51850		12.5		.0048	.054
2JJ 8	465	420	375	330	300	27160	26750	10.03	9.84	48300	47940	52160	51850	11.5	12.0	.0050	.062
2JJ 9	465	420	375	330	300	26690		10.00		47680		51540		12.0		.0052	.073
2JJ 10	465	420	375	330	400	25540		10.00		42310		43540		12.5		.0050	.067
2JJ 11	465	420	375	330	400	20250	20970	9.61	9.73	42520	42240	43610	43480	13.0	12.8	.0050	.068
2JJ 12	465	420	375	330	400	17130		9.58		41900		43300		13.0		.0050	.059
	1.0 Hr.	4.6 Hrs.	25.2 Hrs.	164.0 Hrs.													
2KK 1	510°F	465°F	420°F	375°F	R.T.	23730		10.02		44460		59330		8.5		.0050	.040
2KK 2	510	465	420	375	R.T.	27070	24730	9.71	10.36	44110	43960	58920	58310	8.5	8.5	.0048	.042
2KK 3	510	465	420	375	R.T.	23400		10.46		43310		56690		8.5		.0048	.037
2KK 4	510	465	420	375	200	23240		9.98		40380		51280		9.5		.0046	.074
2KK 5	510	465	420	375	200	23950	24090	10.23	9.92	39480	39830	50650	50860	9.5	9.8	.0051	.074
2KK 6	510	465	420	375	200	25080		9.54		39640		50650		10.5		.0051	.063
2KK 7	510	465	420	375	300	20810		9.41		36930		43230		12.0		.0042	.060
2KK 8	510	465	420	375	300	17790	19610	10.19	9.68	35920	36260	42070	42460	12.0	12.0	.0053	.067
2KK 9	510	465	420	375	300	20230		9.43		35920		42070		12.0		.0054	.071
2KK 10	510	465	420	375	400	16940		8.79		31930		34520		13.5		.0053	.067
2KK 11	510	465	420	375	400	15920	16470	9.23	9.06	32640	32290	35510	35070	13.0	12.8	.0050	.064
2KK 12	510	465	420	375	400	16560		9.16		32320		35190		12.0		.0054	.067
	1.0 Hr.	4.3 Hrs.	21.5 Hrs.	126.1 Hrs.													
2MM 1	555°F	510°F	465°F	420°F	R.T.	17080		9.83		30280		47210		10.0		.0055	.038
2MM 2	555	510	465	420	R.T.	15060	15350	9.65	9.90	29970	30140	47050	47190	10.0	10.0	.0060	.057
2MM 3	555	510	465	420	R.T.	13910		10.23		30160		47340		10.0		.0051	.048
2MM 4	555	510	465	420	200	16250		9.21		29100		42720		11.5		.0066	.065
2MM 5	555	510	465	420	200	8880	13910	9.89	9.61	28820	28880	42680	42650	12.0	11.6	.0058	.056
2MM 6	555	510	465	420	200	16610		9.73		28730		42550		11.5		.0054	.064
2MM 7	555	510	465	420	300	17180		8.75		26720		35000		16.5		.0050	.061
2MM 8	555	510	465	420	300	10940	14890	9.89	9.59	27190	27010	35620	35320	15.0	16.1	.0051	.066
2MM 9	555	510	465	420	300	16560		10.12		27130		35330		17.0		.0058	.050
2MM 10	555	510	465	420	400	13080		8.56		23210		27260		11.5		.0050	.048
2MM 11	555	510	465	420	400	13640	14200	10.39	9.47	24760	24560	29470	28980	18.5	15.9	.0050	.050
2MM 12	555	510	465	420	400	15890		9.45		25700		30220		16.0		.0058	.062

TABLE XXVII (Cont'd)

RESULTS OF TENSILE TESTS OF 2024-T3 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

	1.0 Hr.	6.0 Hrs.	16.6 Hrs.	99.6 Hrs.													
ZII 1	600°F	555°F	510°F	465°F	R.T.	13880		9.85		23300		43210		12.0		.0050	.044
ZII 2	600	555	510	465	R.T.	13930	13930	9.91	9.84	22600	22550	41950	42150	11.0	11.8	.0050	.047
ZII 3	600	555	510	465	R.T.	13970		9.75		21740		41300		11.0		.0047	.053
ZII 4	600	555	510	465	200	13240		9.37		19630		36450		14.0		.0045	.075
ZII 5	600	555	510	465	200	12930	13170	9.61	9.58	18650	18680	35510	35630	16.0	14.8	.0048	.078
ZII 6	600	555	510	465	200	13350		9.76		18170		34940		14.5		.0040	.080
ZII 7	600	555	510	465	300	12970		9.32		18750		30310		16.0		.0050	.070
ZII 8	600	555	510	465	300	11410	11680	9.58	9.48	19370	18970	30620	30340	17.5	16.5	.0050	.076
ZII 9	600	555	510	465	300	10660		9.53		18800		30090		16.0		.0055	.079
ZII 10	600	555	510	465	400	10160		8.72		17190		22970		20.0		.0060	.080
ZII 11	600	555	510	465	400	7160	9450	8.88	8.94	16510	17090	22740	23050	22.5	22.2	.0050	.088
ZII 12	600	555	510	465	400	11020		9.21		17560		23440		22.0		.0049	.082

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

TABLE XXVIII

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 0.1 AND 1.0 HOUR EXPOSURES AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time Hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong.	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
TII1	-	-	200	37500		8.60		62340		68990		16.0		.0054	.069
TII2	-	-	200	37690	36050	9.02	8.79	62180	62120	68040	68810	16.0	15.7	.0047	.069
TII3	-	-	200	32960		8.75		61830		69400		15.0		.0054	.069
TII4	-	-	300	32130		8.49		54220		56720		17.5		.0051	.069
TII5	-	-	300	32870	32370	8.23	8.38	54060	53910	55560	56720	17.0	18.3	.0047	.069
TII6	-	-	300	32120		8.41		53440		55670		20.0		.0051	.069
TII7	-	-	400	18680		7.95		37580		41410		6.5		.0045	.069
TII8	-	-	400	18070	18590	8.05	7.93	38420	38670	41870	41760	15.0	13.5	.0045	.069
TII9	-	-	400	19020		7.79		40000		42000		19.0		.0052	.069
TX 4	300	0.1	R.T.(1)	37580		9.25		65600		76910		12.5		.0060	.067
TX 5	300	0.1	R.T.	38820	37930	9.25	9.25	65820	65540	77260	77020	13.0	12.7	.0060	.067
TX 6	300	0.1	R.T.	37380		9.26		65500		77000		12.5		.0060	.067
TX 7	300	0.1	200	34240		8.94		59870		68310		16.0		.0051	.075
TJ 1	300	0.1	200	29270	31760	9.82	9.38	60760	60320	69150	68760	16.5	16.2	.0047	.075
TJ 2	300	0.1	200	(2)		(2)		(2)		68830		16.0		.0042	.075
TDD1 (3)	300	0.1	200	25960	27860	9.42	9.38	61860	61950	70510	70460	15.5	15.3	.0051	.071
TDD2 (3)	300	0.1	200	29750		9.33		62030		70410		15.0		.0050	.071
TJ 3	300	0.1	300	18730		9.37		52700		56350		19.5		.0048	.067
TJ 4	300	0.1	300	16770	19580	9.06	9.38	52850	52810	56330	56520	18.5	20.3	.0050	.067
TE 1	300	0.1	300	23240		9.72		52880		56890		23.0		.0048	.067
TE 2	300	0.1	400	15020		8.14		39300		42490		14.5		.0053	.057
TE 3	300	0.1	400	19080	16460	8.10	8.17	40460	39930	43420	43100	15.5	15.5	.0053	.057
TE 4	300	0.1	400	15270		8.28		40030		43410		16.5		.0054	.067
TF 38	400	0.1	RT	41530		9.20		62540		72640		10.5		.0068	.054
TF 39	400	0.1	RT	41530	41940	9.20	9.20	62700	62640	72800	72730	10.5	10.5	.0071	.054
TF 40	400	0.1	RT	42760		9.21		62700		72830		10.5		.0073	.054
TF 41	400	0.1	200	39940		8.74		58790		65180		13.5		.0068	.054
TF 42	400	0.1	200	41720	42060	8.40	8.45	58440	58690	64810	64980	15.0	14.0	.0075	.054
TG 1	400	0.1	200	44530		8.20		58840		64950		13.5		.0076	.054
TG 2	400	0.1	300	28800		7.93		51940		54690		16.0		.0076	.054
TG 3	400	0.1	300	32750	29330	8.15	8.08	51750	51830	54150	54510	19.0	17.3	.0071	.054
TG 4	400	0.1	300	26460		8.18		51790		54710		17.0		.0076	.054

TABLE XXVIII (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 0.1 AND 1.0 HOUR EXPOSURES AT ELEVATED TEMPERATURES

TG 5	400	0.1	400	25480		6.70		41610		43250		14.5		.0046	.051
TG 6	400	0.1	400	25850	24000	7.52	7.40	42280	41840	43890	43610	16.0	15.8	.0048	.051
TG 7	400	0.1	400	16880		7.98		41640		43730		17.0		.0050	.051
TG 8	500	0.1	RT	18650		9.54		36170		53380		11.0		.0054	.075
TH 1	500	0.1	RT	19520	19280	9.29	9.55	36130	36090	53550	52840	11.0	10.8	.0053	.075
TH 2	500	0.1	RT	19680		9.83		35970		51610		10.5		.0053	.075
TH 3	500	0.1	200	17680		8.97		36330		47110		17.5		.0061	.075
TH 4	500	0.1	200	20640	18950	9.00	9.52	36130	36300	47100	47210	15.5	16.6	.0061	.075
TH 5	500	0.1	200	18550		10.60		36450		47420		17.0		.0054	.075
TH 6	500	0.1	300	19170		8.92		33550		36740		25.0		.0055	.075
TH 7	500	0.1	300	18790	18870	8.96	8.87	33440	33420	36620	36630	22.5	24.5	.0054	.075
TH 8	500	0.1	300	18670		8.74		33280		36530		26.0		.0054	.075
TI 1	500	0.1	400	13580		10.83		28310		28910		19.5		.0046	.061
TI 2	500	0.1	400	11530	13160	9.47	10.12	27710	27990	28340	28590	27.0	22.0	.0047	.061
TI 3	500	0.1	400	14390		10.05		27950		28520		19.5		.0041	.061
TK 7	300	1.0	R.T.	38690		9.10		63220		74840		13.0		.0050	.067
TK 8	300	1.0	R.T.	37660	38400	9.33	9.17	63690	63320	75640	73940	12.0	12.3	.0050	.067
TL 1	300	1.0	R.T.	38850		9.10		63060		71340		12.0		.0050	.067
TL 5	300	1.0	200	35830		8.71		59550		67830		18.5		.0050	.067
TL 6	300	1.0	200	27940	31340	9.44	9.08	59210	59490	67940	68020	17.0	18.5	.0051	.067
TL 7	300	1.0	200	30260		9.10		59710		68310		20.0		.0050	.067
TL 8	300	1.0	300	31330		8.71		51900		55240		17.0		.0047	.067
TM 1	300	1.0	300	31250	30980	8.80	8.73	51760	51810	55290	55370	17.0	18.0	.0052	.067
TM 2	300	1.0	300	30350		8.71		51760		55590		20.0		.0051	.067
TM 3	300	1.0	400	17680		7.83		39650		42200		18.5		.0050	.051
TM 4	300	1.0	400	15450	17160	8.00	7.85	39460	39370	42170	42030	16.0	17.2	.0050	.051
TM 5	300	1.0	400	17350		7.76		39010		41720		17.0		.0052	.051
TC 34	400	1.0	R.T.	38150		9.08		54060		65910		10.0		.0050	.051
TC 35	400	1.0	R.T.	35820	35010	9.15	9.31	53770	54060	65900	66050	10.5	10.3	.0050	.051
TD 21	400	1.0	R.T.	32040		9.71		54370		66340		10.5		.0050	.051
TB 16	400	1.0	200	34920		8.40		49180		55570		14.5		.0055	.051
TB 17	400	1.0	200	27100	30680	9.13	8.82	49190	49400	55840	55860	14.5	14.1	.0055	.051
TB 18	400	1.0	200	30030		8.95		49840		56170		13.5		.0052	.051
TB 13	400	1.0	300	24920		9.49		44340		46120		19.5		.0059	.057
TB 14	400	1.0	300	21310	22920	9.00	9.06	45410	44990	47050	46680	17.0	19.0	.0062	.057
TB 15	400	1.0	300	22530		8.71		45230		46880		20.5		.0062	.057
TB 19	400	1.0	400	16450		7.67		35340		36970		21.0		.0050	.051
TB 20	400	1.0	400	15030	15990	7.84	7.59	35620	35470	37090	36880	17.5	18.5	.0054	.051
TC 32	400	1.0	400	16500		7.26		35460		36600		17.0		.0054	.051

TABLE XXVIII (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 0.1 AND 1.0 HOUR EXPOSURES AT ELEVATED TEMPERATURES

TD 22	500	1.0	R.T.	15530	14250	13.33	9.89	25570	25680	44150	44180	10.0	10.2	.0103	.061
TD 23	500	1.0	R.T.	13390		10.03		25650		44160		10.5		.0144	.061
TD 25	500	1.0	R.T.	16100		9.19		25820		44240		10.0		.0106	.061
TD 29	500	1.0	300	16070	12760	8.74	9.10	25570	25430	39020	39100	18.0	18.2	.0062	.022
TD 30	500	1.0	300	10360		9.46		25160		39150		18.5		.0067	.022
TD 31	500	1.0	300	11350		9.32		25430		39140		18.0		.0052	.022
TD 24	500	1.0	350	14660	14120	8.74	9.01	24590	24[illegible]	29140	29160	30.5	31.0	.0036	.034
TD 25	500	1.0	350	12770		9.16		24640		28960		29.5		.0036	.034
TD 26	500	1.0	350	15130		9.11		24120		29530		33.0		.0036	.034
TP 43	500	1.0	400	11510	11990	8.67	7.87	21090	20900	21530	21250	29.5	27.6	.0067	.030
TP 35	500	1.0	400	12010		7.73		[illegible]		21270		25.0		.0050	.030
TP 37	500	1.0	400	11600		7.23		20570		20930		29.5		.0060	.030

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 65-85°F.

(2) Autographic strain recorder graph unsatisfactory for determining subject properties.

(3) Tested specimens to fulfill requirement of at least three good specimens per testing condition.

TABLE XXIX

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER 10 AND 100 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temp. °F	Exposure Time Hrs.	Testing Temp. °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. %	Average Elong. in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
7P 4	500	10.0	R.T.(1)	54030		9.40		64080		75000		12.0		.0038	.061
7P 1	500	10.0	R.T.	57220	55290	9.40	9.39	66020	65290	76210	75810	12.0	12.0	.0041	.061
7P 11	500	10.0	R.T.	54570		9.33		65760		76210		12.0		.0039	.061
7P 2	500	10.0	200	42560		8.46		61070		66100		15.5		.0032	.075
7P 3	500	10.0	200	42400	42280	8.53	8.62	61750	61500	67310	66950	15.0	15.0	.0033	.075
7P 4	500	10.0	200	41990		8.86		61690		67370		16.5		.0032	.075
7P 6	500	10.0	300	16500		9.63		53260		55150		18.0		.0047	.075
7P 7	500	10.0	300	17800	16630	9.10	9.23	52700	52220	55660	55310	15.[illegible]	17.5	.0048	.075
7P 1	500	10.0	300	15630		8.94		51450		54700		19.5		.0049	.075
7P 8	500	10.0	400	7605		9.00		39670		42070		16.0		.0052	.075
7P 9	500	10.0	400	7795	7670	8.84	8.80	39253	38950	42760	42380	16.0	16.5	.0053	.075
7P 10	500	10.0	400	6613		8.57		38940		42510		17.5		.0053	.075
74 1	400	10.0	R.T.	18030		9.73		55060		50650		9.5		.0051	.081
74 2	400	10.0	R.T.	19570	18130	10.10	9.84	55110	54990	50310	50390	10.5	9.8	.0050	.081
74 3	400	10.0	R.T.	19000		9.70		54790		50320		9.5		.0051	.081
74 4	400	10.0	200	16670		9.12		55170		42230		18.0		.0051	.075
74 5	400	10.0	200	19480	17390	9.21	9.24	55600	55420	42530	42410	16.0	17.5	.0051	.075
74 6	400	10.0	200	16020		9.41		55500		42480		18.5		.0051	.075
74 7	400	10.0	300	11490		9.92		30580		32350		24.5		.0010	.075
74 8	400	10.0	300	9978	10240	10.16	9.96	30580	30570	32170	32280	23.5	25.6	.0040	.075
74 9	400	10.0	300	9646		9.81		30550		32320		29.0		.0047	.075
74 10	400	10.0	400	12640		7.70		24920		25400		33.5		.0053	.075
74 11	400	10.0	400	13050	13160	7.90	7.76	25140	25110	25470	25490	24.5	27.6	.0050	.075
74 12	400	10.0	400	13000		7.69		25260		25610		25.0		.0051	.075
7H 6	500	10.0	R.T.	7078		10.66		18330		37700		12.0		.0050	.054
7H 7	500	10.0	R.T.	7258	8110	10.32	10.30	18390	18380	37900	37850	12.5	12.5	.0050	.054
7H 8	500	10.0	R.T.	9199		9.92		18430		37930		13.0		.0050	.051
74 5	500	10.0	R.T.	11010		9.92		20100		37580		11.0		.0054	.071
74 9	500	10.0	R.T.	8380	9960	9.12	9.39	17860	18550	37740	37610	12.5	12.0	.0048	.071
74 10	500	10.0	R.T.	10050		9.12		17700		37500		12.5		.0045	.071

TABLE XXIX (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 10 AND 100 HOURS EXPOSURE AT ELEVATED TEMPERATURES

TG 1	500	10.0	200	7878		10.72		18100		35050		17.0		.0049	.061
TG 2	500	10.0	200	8360	7930	10.46	10.31	18330	18250	35050	35050	17.5	17.3	.0047	.061
TG 3	500	10.0	200	7556		9.75		18330		35050		17.5		.0050	.061
TDD 3	500	10.0	200	10410		9.49		17820		35760		14.5		.0045	.069
TDD 4	500	10.0	200	9810	10020	9.49	9.42	17030	17270	35600	35640	14.5	14.8	.0048	.069
TDD 5	500	10.0	200	9840		9.29		16950		35560		15.5		.0048	.069
TH 4	500	10.0	300	9678		8.64		17560		23730		51.0		.0050	.075
TH 5	500	10.0	300	10310	9860	9.39	8.98	17570	17580	24030	24010	49.0	52.5	.0051	.075
TH 6	500	10.0	300	9393		8.93		17510		24280		57.5		.0049	.075
TDD 6	500	10.0	300	9630		9.37		16950		24540		47.0		.0045	.069
TDD 7	500	10.0	300	8620	8980	9.97	9.51	17040	16980	24600	24600	48.0	45.7	.0045	.069
TDD 8	500	10.0	300	8650		9.19		16870		24650		42.0		.0048	.069
TDD 9	500	10.0	400	7860		8.36		14940		16250		47.5		.0045	.069
TDD10	500	10.0	400	7290	7300	8.99	8.42	14980	14940	16310	16280	46.5	48.2	.0048	.069
TDD11	500	10.0	400	6760		7.91		14910		16260		50.5		.0048	.069
TE 7	500	10.0	400	10060		7.52		15400		16640		55.0		.0053	.075
TO 1	(4)	(4)	(4)	(4)	9904	(4)	7.44	(4)	15550	(4)	16610	(4)	56.0	(4)	(4)
TO 2	500	10.0	400	9747		7.36		15700		16580		57.0		.0053	.075
TU 3	250	100.0	R.T.	45940		8.85		67340		76560		14.0		.0053	.061
TU 4	250	100.0	R.T.	46090	46820	8.97	8.90	67340	67390	76560	76610	12.0	13.2	.0054	.061
TU 5	250	100.0	R.T.	48440		8.87		67500		76720		13.5		.0051	.061
TU 6	250	100.0	200	38440		9.20		62500		67970		15.0		.0051	.061
TU 7	250	100.0	200	34060	34010	9.46	9.38	62190	62290	67970	67920	18.0	16.7	.0051	.061
TU 8	250	100.0	200	29530		9.47		62190		67810		17.0		.0050	.061
TU 9	250	100.0	300	30090		8.51		55780		56830		21.5		.0058	.061
TU 10	250	100.0	300	28210	30090	8.45	8.44	54860	55170	56580	56680	18.5	20.8	.0048	.061
TU 11	250	100.0	300	31980		8.35		54860		56580		22.5		.0052	.061
TU 12	250	100.0	400	26800		6.99		41690		42950		19.0		.0058	.067
TW 1	250	100.0	400	28660	27060	6.96	7.17	41720	41910	42680	42970	18.5	18.7	.0052	.067
TT 2	250	100.0	400	25720		7.55		42330		43290		18.5		.0048	.067
TZ 2	300	100.0	R.T.	37600		8.71		56010		66610		11.0		.0050	.086
TZ 3	300	100.0	R.T.	37500	37200	8.68	8.71	55950	55890	66610	66580	11.0	10.8	.0051	.086
TZ 4	300	100.0	R.T.	36510		8.74		55710		66510		10.5		.0051	.086
TZ 5	300	100.0	200	36740		8.47		52300		56870		13.0		.0050	.081
TZ 6	300	100.0	200	36380	36660	8.88	8.73	52500	52450	57210	57100	12.5	13.2	.0050	.081
TZ 7	300	100.0	200	35860		8.83		52560		57210		14.0		.0049	.081
TJ 2	300	100.0	300	27970		8.84		46250		47340		24.0		.0050	.077
TZ 9	300	100.0	300	29550	28670	8.15	8.58	46520	46280	47470	47320	16.0	19.3	.0049	.077
TZ 10	300	100.0	300	28390		6.74		46060		47160		19.5		.0046	.077

TABLE XXIX (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 10 AND 100 HOURS EXPOSURE AT ELEVATED TEMPERATURES

TT 11	300	100.0	400	21230		7.95		36010		35790		17.5		.0050	.075
TT 12	300	100.0	400	17970	19320	7.16	7.55	35620	36170	35410	36950	18.5	16.8	.0051	.075
TT 1	300	100.0	400	18750		7.84		[illegible]		[illegible]		14.5		[illegible]	.075
TT 12	400	101.0	R.T.(1)	10770		[illegible]		[illegible]		[illegible]		11.0		[illegible]	.050
TT 13	400	101.0	R.T.	11900	[illegible]	[illegible]	9.37	[illegible]	[illegible]	[illegible]	[illegible]	10.0	[illegible]	.0051	.050
TT 2	400	101.0	R.T.	11710		[illegible]		[illegible]		[illegible]		11.0		[illegible]	.050
TT 3	400	101.0	200	13020		9.22		[illegible]		[illegible]		17.5		.0054	.091
TT 4	400	101.0	200	(2)	1723[illegible]	(2)	[illegible]	(2)	[illegible]	[illegible]	[illegible]	17.0	16.5	.0053	.091
TB 5	400	101.0	200	1254[illegible]		8.39		[illegible]		[illegible]		16.0		.0050	.091
TB 7(3)	400	101.0	200	11040	11380	10.17	10.27	22550	22750	35650	35940	17.5	17.0	.0053	.069
TB 8(3)	400	101.0	200	12710		10.35		22930		36220		15.5		.0050	.069
TB 6	400	101.0	300	11340		9.89		21240		25000		42.0		.0050	.086
TB 7	400	101.0	300	12100	11000	8.90	9.53	21270	21250	25030	25050	37.0	39.3	.0051	.086
TB 8	400	101.0	300	9556		9.81		21270		25110		39.0		.0050	.086
TB 9	400	101.0	400	8599		7.70		18180		18600		38.0		.0050	.086
TB 10	400	101.0	400	7930	8279	7.39	7.66	18150	18150	18570	18550	45.0	39.7	.0048	.086
TB 11	400	101.0	400	8300		7.89		18120		18470		36.0		.0048	.086
TTF 1	500	100.0	R.T.	7550		9.32		15450		35670		16.0		.0100	.069
TTF 2	500	100.0	R.T.	7640	7280	9.23	9.11	15290	15310	35190	35330	14.0	14.8	.0074	.069
TTF 3	500	100.0	R.T.	6650		8.78		15190		35130		14.5		.0069	.069
TTF 4	500	100.0	200	9780		9.12		15460		33440		14.5		.0064	.069
TTF 5	500	100.0	200	9210	9250	9.20	9.22	15390	15390	33600	33480	15.0	15.0	.0066	.069
TTF 6	500	100.0	200	8770		9.34		15320		33390		15.5		.0071	.069
TTF 7	500	100.0	300	8460		9.37		23860		23860		47.0		.0057	.069
TTF 8	500	100.0	300	7300	8140	9.25	9.33	14890	17840	23850	23800	40.5	45.2	.0058	.069
TTF 9	500	100.0	300	8650		9.36		14780		23680		48.0		.0054	.069
TTF10	500	100.0	400	7990		8.24		13370		15220		66.0		.0054	.069
TTF11	500	100.0	100	6270	7290	8.42	8.36	13350	13270	15170	15120	64.5	60.8	.0062	.069
TTF12	500	100.0	400	7620		8.43		13090		14980		52.0		.0058	.069

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60 - 85°F.

(2) Autographic strain recorder curve was unsatisfactory for determining subject properties.

(3) Retest specimens to fulfill requirement of at least three good specimens per testing condition.

(4) Pin joint hole defective. Unable to perform testing.

TABLE XXX

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 1000 HOURS EXPOSURE AT ELEVATED TEMPERATURES

Specimen No.	Exposure Temperature °F	Exposure Time Hrs.	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong.	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
7Z 1	250	1000.0	R.T.(1)	(2)		(2)		(2)		72900		11.5		.0048	.071
7Z 2	250	1000.0	R.T.	44680	44300	9.41	9.06	61610	61820	72740	72690	11.5	11.5	.0046	.071
7Z 3	250	1000.0	R.T.	43910		8.71		62020		72440		11.5		.0048	.071
7Z 4	250	1000.0	200	40070		8.50		57930		62460		14.5		.0049	.071
7Z 5	250	1000.0	200	39420	39880	8.51	8.57	57530	57840	62180	62460	13.0	14.2	.0051	.071
7Z 6	250	1000.0	200	40160		8.71		58070		62740		15.0		.0051	.071
7Z 7	250	1000.0	300	32120		7.59		49680		51280		17.0		.0051	.071
7Z 8	250	1000.0	300	36740	34870	7.59	7.50	47920	49200	51280	51220	16.0	18.2	.0050	.071
7Z 9	250	1000.0	300	35760		7.32		50000		51110		21.5		.0053	.071
7Z 10	250	1000.0	400	11780		8.56		36470		38220		21.0		.0050	.069
7Z 11	250	1000.0	400	12250	12110	8.50	8.47	36710	36910	38130	38170	17.0	19.2	.0050	.069
7Z 12	250	1000.0	400	12300		8.36		37540		38170		19.5		.0050	.069
7ZZ 1	300	1000.0	R.T.	20570		9.44		37820		52220		10.5		.0061	.081
7ZZ 2	300	1000.0	R.T.	20660	20830	9.17	9.32	38170	38220	52370	52360	10.5	10.5	.0061	.081
7ZZ 3	300	1000.0	R.T.	21250		9.35		38660		52500		10.5		.0059	.081
7ZZ 4	300	1000.0	200	21230		9.41		37740		45440		17.0		.0061	.081
7ZZ 5	300	1000.0	200	27520	23870	8.71	9.09	37740	37780	45280	45380	16.0	16.5	.0053	.081
7ZZ 6	300	1000.0	200	22870		9.15		37850		45430		16.5		.0056	.081
7ZZ 7	300	1000.0	300	19400		9.02		33440		34540		20.0		.0056	.081
7ZZ 8	300	1000.0	300	19620	19830	8.50	8.38	33540	33540	34650	34700	21.5	22.3	.0056	.081
7ZZ 9	300	1000.0	300	20480		8.60		33650		34920		25.5		.0054	.081
7ZZ 10	300	1000.0	400	12080		8.15		27220		27540		28.0		.0053	.069
7ZZ 11	300	1000.0	400	8970	10330	8.69	8.36	26670	26780	27020	27120	22.0	24.8	.0051	.069
7ZZ 12	300	1000.0	400	9940		8.24		26440		26800		24.5		.0051	.069
7X 1	400	1000.0	R.T.	10100		10.58		17270		34760		12.5		.0053	.081
7X 2	400	1000.0	R.T.	10320	10210	9.33	9.55	17650	17440	34920	34780	12.0	12.3	.0054	.081
7X 3	400	1000.0	R.T.	10220		8.76		17410		34650		12.5		.0053	.081

TABLE XXX (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER 1000 HOURS EXPOSURE AT ELEVATED TEMPERATURES

7T	4	400	1000.0	200	7830		10.05		15930		31050		17.0		.0051	.071
7T	5	400	1000.0	200	8280	8660	10.22	10.13	17200	17110	31080	31070	17.5	17.3	.0051	.071
7T	6	400	1000.0	200	9870		10.12		17260		31080		17.5		.0050	.071
7T	7	400	1000.0	300	7640		10.50		16430		21400		54.0		.0043	.081
7T	8	400	1000.0	300	7140	7380	10.11	10.46	16430	16390	21380	21340	53.5	56.8	.0045	.081
7T	9	400	1000.0	300	7370		10.77		16280		21250		63.0		.0048	.081
7T	10	400	1000.0	400	7600		8.67		14530		15320		49.5		.0050	.081
7T	11	400	1000.0	400	6650	7530	9.65	9.14	14470	14580	15180	15280	51.5	52.1	.0045	.081
7T	12	400	1000.0	400	8330		9.11		14600		15350		55.5		.0048	.081
7A	1	500	1000.0	R.T.	7320		10.15		14050		32840		13.5		.0047	.081
7A	2	500	1000.0	R.T.	6480	7530	10.11	9.87	13990	14080	32300	32640	14.0	14.5	.0054	.075
7A	3	500	1000.0	R.T.	8950		9.34		14200		32790		16.0		.0050	.075
7A	4	500	1000.0	200	8600		11.12		14590		30810		21.0		.0037	.075
7A	5	500	1000.0	200	6980	7970	10.21	10.47	14220	14400	30650	30790	20.0	20.3	.0043	.075
7A	6	500	1000.0	200	8330		10.09		14390		30920		20.0		.0040	.075
7A	7	500	1000.0	300	6720		10.74		13970		22820		46.5		.0031	.075
7A	8	500	1000.0	300	7700	6930	8.48	9.96	13880	13940	22860	22790	58.0	53.5	.0033	.075
7B	1	500	1000.0	300	6360		10.66		13970		22690		56.0		.0031	.075
7B	2	500	1000.0	400	(2)		(2)		(2)		14590		91.5		.0028	.075
7B	3	500	1000.0	400	8430	7480	8.89	8.75	12920	12750	15480	14950	76.5	83.5	.0027	.075
7B	4	500	1000.0	400	6540		8.60		12580		14770		82.6		.0030	.075

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) Autographic strain recorder curve was unsatisfactory for determining subject properties.

TABLE XXXI

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen No.	Sequential Exposure Time & Temp. First 1.5 Hr. °F	Second 10 Hrs. °F	Third 100 Hrs. °F	Fourth 1000 Hrs. °F	Testing Temp. °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Ave. Elong. % in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
7V 3	400	300	-	-	R.T.(1)	37260		8.82		53940		65320		11.0		.0070	.061
7V 4	400	300	-	-	R.T.	37160	37490	8.75	8.77	54640	54450	65770	65990	10.5	11.0	.0060	.061
7V 5	400	300	-	-	R.T.	38040		8.73		55150		66670		11.5		.0060	.061
7V 6	400	300	-	-	200	36820		8.17		53340		58040		13.5		.0058	.061
7V 7	400	300	-	-	200	39200	36280	8.01	8.10	52280	52370	56890	57260	14.5	14.1	.0060	.061
7V 8	400	300	-	-	200	32830		8.35		51500		56850		14.5		.0071	.061
7V 9	400	300	-	-	300	33090		7.38		45530		46330		20.0		.0076	.061
7V 10	400	300	-	-	300	32540	32500	7.82	7.50	44970	45320	45510	45950	17.0	19.0	.0071	.061
7V 11	400	300	-	-	300	33630		7.30		45450		46020		20.0		.0066	.061
7V 12	400	300	-	-	400	17410		8.04		36170		36100		20.0		.0076	.075
7W 1	400	300	-	-	400	19100	18870	8.04	8.04	34970	35790	35740	36110	20.0	21.0	.0071	.061
7W 2	400	300	-	-	400	20120		8.04		36240		36500		23.0		.0076	.061
7W 3	400	300	250	-	R.T.	37400		8.61		53260		64540		10.5		.0071	.054
7W 4	400	300	250	-	R.T.	35050	36930	8.79	8.67	53630	54060	64950	65230	11.0	10.8	.0080	.054
7W 5	400	300	250	-	R.T.	37340		8.60		55290		66190		11.0		.0071	.054
7W 6	400	300	250	-	200	37370		8.64		52720		57530		14.5		.0066	.054
7W 7	400	300	250	-	200	38040	37480	9.23	8.96	52530	52400	57210	57140	14.0	13.6	.0066	.054
7W 8	400	300	250	-	200	37340		9.01		51040		56690		12.5		.0066	.054
7W 9	400	300	250	-	300	31580		8.04		45320		46200		16.5		.0071	.054
7W 10	400	300	250	-	300	28320	29700	8.62	8.29	44970	45310	45890	46210	19.5	17.6	.0069	.054
7W 11	400	300	250	-	300	29210		8.22		45630		46530		17.0		.0071	.054
7W 12	400	300	250	-	400	21350		7.68		36260		36950		19.5		.0076	.054
7X 1	400	300	250	-	400	23410	20450	8.54	8.31	36230	36120	36710	36670	21.0	19.5	.0071	.054
7X 2	400	300	250	-	400	19590		8.72		35870		36350		18.0		.0071	.054
7AA 1	500	400	-	-	R.T.	12660		10.54		25480		42880		10.0		.0057	.061
7AA 2	500	400	-	-	R.T.	14690	13970	9.61	9.81	25840	25700	43120	43020	10.0	10.2	.0047	.069
7AA 3	500	400	-	-	R.T.	14570		9.27		25770		43060		10.5		.0042	.069
7AA 4	500	400	-	-	200	15301		8.91		25310		37190		20.5		.0047	.069
7AA 5	500	400	-	-	200	17240	155	8.60	8.96	25460	25410	37220	37240	20.5	19.6	.0045	.069
7AA 6	500	400	-	-	200	15830		9.16		25460		37300		18.0		.0044	.069

TABLE XXXI (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER A SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

7AA 7	500	400	-	-	300	12410		9.23		23880		27340		43.5		.0063	.069
7AA 8	500	400	-	-	300	13910	12490	8.68	9.19	23750	23800	26620	26930	35.0	35.2	.0048	.069
7AA 9	500	400	-	-	300	11140		9.67		23770		26840		27.0		.0048	.069
7AA10	500	400	-	-	400	8550		8.60		19970		20160		35.0		.0046	.069
7AA11	500	400	-	-	400	10790	9650	10.44	10.09	20130	20110	20130	20220	36.5	34.8	.0041	.069
7AA12	500	400	-	-	400	9620		11.16		20220		20380		33.0		.0043	.069
7BB 1	500	400	300	-	R.T.	10680		10.79		26700		42720		11.0		.0055	.069
7BB 2	500	400	300	-	R.T.	12930	12770	11.25	10.77	26500	26600	42930	42860	10.5	10.7	.0051	.069
7BB 3	500	400	300	-	R.T.	14730		10.29		26590		42930		10.5		.0045	.069
7BB 4	500	400	300	-	200	16430		9.52		26010		36660		18.0		.0045	.069
7BB 5	500	400	300	-	200	16990	15790	8.47	9.15	25930	25910	36380	36510	18.0	18.7	.0045	.069
7BB 6	500	400	300	-	200	13990		9.45		25790		36500		18.5		.0045	.069
7BB 7	500	400	300	-	300	14300		10.03		24040		26350		34.0		.0039	.069
7BB 8	500	400	300	-	300	14290	14100	10.03	10.27	24030	24070	26420	26410	37.0	33.3	.0040	.069
7BB 9	500	400	300	-	300	13710		10.75		24130		26450		29.0		.0042	.069
7BB10	500	400	300	-	400	9740		8.97		20160		20260		34.5		.0046	.071
7BB11	500	400	300	-	400	11420	10660	8.58	8.93	20030	20040	20130	20200	31.0	32.2	.0046	.071
7BB12	500	400	300	-	400	13620		9.25		19940		20200		31.0		.0048	.071
7CC 1	500	400	300	250	R.T.	13510		10.26		26530		42200		10.5		.0044	.061
7CC 2	500	400	300	250	R.T.	16250	15460	11.83	11.37	26350	26360	42470	42360	11.5	10.7	.0050	.069
7CC 3	500	400	300	250	R.T.	16610		12.02		26200		42330		10.5		.0046	.069
7CC 4	500	400	300	250	200	15290		9.38		25320		35740		18.0		.0048	.069
7CC 5	500	400	300	250	200	16810	15940	9.68	9.41	25320	25300	35810	35710	17.0	18.5	.0046	.069
7CC 6	500	400	300	250	200	15280		9.16		25260		35580		20.5		.0051	.069
7CC 7	500	400	300	250	300	14670		8.40		23300		25740		34.0		.0052	.069
7CC 8	500	400	300	250	300	14640	14110	8.79	8.61	23390	23400	25720	25780	32.5	32.0	.0052	.069
7CC 9	500	400	300	250	300	14050		8.63		23510		25890		29.5		.0050	.069
7CC10	500	400	300	250	400	10000		8.17		19750		19910		30.0		.0055	.069
7CC11	500	400	300	250	400	10600	9650	8.23	8.54	19940	19890	20030	19970	34.0	29.5	.0056	.069
7CC12	500	400	300	250	400	8350		9.22		19970		20030		24.5		.0055	.069

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60 - 85°F

TABLE XXXII

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

Specimen Number	Sequential Exposure Time and Temperature: First	Second	Third	Fourth	Testing Temperature °F	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity X 10^6 psi	Average Modulus of Elasticity X 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elong. % in 2"	Avg. Elong. % in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
	1.0 Hr.	4.8 Hrs.	27.6 Hrs.	191.7 Hrs.													
7XX 1	380°F	340°F	300°F	260°F	R.T.(1)	15000		10.03		53870		66130		11.0		.0055	.074
7XX 2	380	340	300	260	R.T.	15080	14060	10.08	10.21	53970	53810	65820	66030	10.5	10.8	.0044	.48
7XX 3	380	340	300	260	R.T.	12100		10.43		53560		66150		10.5		.0051	.054
7XX 4	380	340	300	260	200	20190		9.88		52650		57490		15.0		.0048	.042
7XX 5	380	340	300	260	200	17000	18730	10.31	10.03	52640	52790	57660	57690	14.5	14.2	.0050	.050
7XX 6	380	340	300	260	200	18990		9.92		53070		57930		13.0		.0054	.055
7XX 7	380	340	300	260	300	23810		9.56		47780		49080		19.5		.0048	.054
7XX 8	380	340	300	260	300	16330	19840	9.75	9.85	49300	48620	50590	49970	17.5	17.7	.0050	.065
7XX 9	380	340	300	260	300	19380		10.25		48770		50230		16.0		.0050	.050
7XX 10	380	340	300	260	400	13980		9.46		37720		39510		16.5		.0049	.046
7XX 11	380	340	300	260	400	14930	15960	10.03	9.59	39110	38900	40570	40310	15.5	15.8	.0052	.056
7XX 12	380	340	300	260	400	18970		9.29		39880		40850		15.5		.0048	.045
	1.0 Hr.	4.5 Hrs.	23.4 Hrs.	145.1 Hrs.													
7JJ 1	420°F	380°F	340°F	300°	R.T.	24280		9.36		38880		52540		11.0		.0050	.040
[illegible]	420	380	340	300	R.T.	23090	22530	8.94	9.14	38690	38660	52670	52640	11.0	10.8	.0054	.057
7JJ 3	420	380	340	300	R.T.	20220		9.12		38400		52510		10.5		.0051	.054
[illegible]	420	380	340	300	200	24340		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	380	340	300	[illegible]	22770	23350	9.47	9.30	36520	36970	44110	44410	16.5	16.2	.0054	.048
7JJ 6	420	380	340	300	200	22430		9.27		37020		44550		15.0		.0054	.055
7JJ 7	420	380	340	300	300	20420		8.95		33760		34880		24.5		.0058	.048
7JJ 8	420	380	340	300	300	16930	19440	9.19	8.95	35550	34070	34840	34690	23.5	23.7	.0053	.052
7JJ 9	420	380	340	300	300	20970		8.71		32900		34350		23.0		.0053	.054
7JJ 10	420	380	340	300	400	13710		9.84		26930		27580		20.0		.0056	.057
7JJ 11	420	380	340	300	400	13180	12990	9.22	9.55	26210	26370	26850	27120	23.0	20.7	.0050	.055
7JJ 12	420	380	340	300	400	12090		9.59		25970		26930		19.0		.0050	.052
	1.0 Hr.	4.2 Hrs.	20.2 Hrs.	113.4 Hrs.													
7HH 1	460°F	420°F	380°F	340°F	R.T.	13380		9.29		27270		43450		10.0		.0046	.069
7HH 2	460	420	380	340	R.T.	17550	14540	9.06	9.29	27520	27380	43460	43450	10.0	10.0	.0048	.069
7HH 3	460	420	380	340	R.T.	12690		9.53		27340		43450		10.0		.0050	.069
7HH 4	460	420	380	340	200	12350		9.83		26770		37300		16.0		.0051	.069
7HH 5	460	420	380	340	200	15530	15480	9.31	9.47	26600	26890	36950	37050	16.0	16.0	.0050	.069
7HH 6	460	420	380	340	200	18580		9.27		27320		36910		16.0		.0048	.069
7HH 7	460	420	380	340	300	11170		9.38		25000		26360		20.0		.0046	.069
7HH 8	460	420	380	340	300	13160	12720	8.80	8.98	25170	25220	27080	26860	20.0	26.0	.0051	.069
7HH 9	460	420	380	340	300	13820		8.75		25480		27140		38.0		.0051	.069
7HH 10	460	420	380	340	400	11790		8.37		21550		21670		25.0		.0051	.069
7HH 11	460	420	380	340	400	13250	12950	8.13	8.23	21390	21490	21520	21610	27.5	26.1	.0048	.069
7HH 12	460	420	380	340	400	13800		8.19		21530		21650		26.0		.0049	.069

TABLE XXXII (Cont'd)

RESULTS OF TENSILE TESTS OF 7075-T6 ALCLAD SHEET AT ROOM AND ELEVATED TEMPERATURES
AFTER AN ADDITIONAL SEQUENCE OF EXPOSURES AT ELEVATED TEMPERATURES

	1.0 Hr.	4.0 Hrs.	17.5 Hrs.	90.5 Hrs.												
7GG 1	500°F	460°F	420°F	380°F	R.T.	12260		9.22		20350		36790		12.0		.0057	.069
7GG 2	500	460	420	380	R.T.	11000	12020	9.04	9.06	20690	20560	37260	37080	11.0	11.5	.0057	.069
7GG 3	500	460	420	380	R.T.	12810		8.91		20630		37190		11.5		.0056	.069
7LL 1	500	460	420	380	200	15920		8.54		20700		34080		20.5		.0060	.060
7LL 2	500	460	420	380	200	17190	16090	8.86	8.71	21500	21040	34550	34320	20.5		.0056	.058
7LL 3	500	460	420	380	200	15170		8.73		20930		34340		20.0		.0050	.068
7GG 7	500	460	420	380	300	9880		8.77		19350		23060		44.0		.0052	.067
7GG 8	500	460	420	380	300	9940	10150	8.62	8.68	19410	19460	23320	23300	45.0	44.7	.0057	.067
7GG 9	500	460	420	380	300	10650		8.64		19630		23520		45.0		.0051	.067
7GG 10	500	460	420	380	400	10900		8.02		16880		17070		44.0		.0050	.067
7GG 11	500	460	420	380	400	8730	9720	8.98	8.53	16840	16890	17030	17070	50.0	46.8	.0050	.067
7GG 12	500	460	420	380	400	9540		8.60		16970		17120		46.5		.0046	.067

(1) R.T. designates room temperature. Actual temperature was not measured but was known to be in the range 60-85°F.

(2) Malfunction of tensile test equipment and test could not be performed.

TABLE XXXIII

ROOM TEMPERATURE TENSILE TEST RESULTS OF 2024-T3 ALCLAD SHEET FOR COMPARISON WITH ELEVATED TEMPERATURE RESULTS

Specimen No.	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elongation % in 2"	Average Elongation % in 2"	Strain Rate Below Yield in./in./min.	Head Travel in Plastic Range in./min.
2AC 1 2AC2	(1) 22800	22800	(1) 10.05	10.05	42830 43550	43190	68470 66510	67490	18.5 20.0	19.3	(2) (2)	(2) (2)
2BC 1 2BC 2	20620 15260	17940	10.03 10.60	10.62	42970 43300	43140	67500 67450	67480	21.0 21.0	21.0	(2) (2)	(2) (2)
2CC 1 2CC 2	17130 26090	21610	10.20 9.76	9.98	43770 44100	43940	65230 66010	66120	22.0 21.0	21.0	(2) (2)	(2) (2)
2DC 1 2DC 2	26090 22330	24210	9.52 10.23	9.88	44220 44030	44130	67340 68240	67790	19.5 21.0	20.3	.0050 .0050	.061 .061
2EC 1 2EC 2	24920 21250	23090	10.34 10.56	10.45	44550 44530	44540	68540 68590	68570	20.0 20.0	20.0	.0048 .0046	.061 .061
2FC 1 2FC 2	23840 23050	23450	10.57 10.10	10.34	44740 44700	44720	68890 68540	68720	20.0 20.0	20.0	.0050 .0052	.044 .044
2GC 1 2GC 2	22520 22340	22430	10.27 10.53	10.40	44250 44380	44320	67550 67500	67530	19.0 19.0	19.0	.0050 .0050	.048 .048
2HC 1 2HC 2	22030 20250	21140	10.46 10.61	10.54	44380 44080	44230	67810 67910	67860	19.5 22.5	21.0	.0052 .0050	.075 .075
2IC 1 2IC 2	20060 17080	18570	10.10 10.52	10.31	44980 44670	44830	68810 68970	68890	19.5 21.0	20.3	.0062 .0058	.067 .067
2JC 1 2JC 2	18850 19470	19160	10.14 10.24	10.19	43610 43610	43610	66510 66670	66590	19.5 19.0	19.3	.0054 .0052	.086 .086
2KC 1 2KC 2	21230 19140	20180	9.96 10.35	10.16	43690 43830	43760	66620 67280	66950	19.0 19.5	19.3	.0054 .0051	.086 .086
2LC 1 2LC 2	18320 18270	18290	10.31 10.18	10.24	43940 43960	43950	67550 67800	67670	21.0 20.0	20.5	.0050 .0053	.086 .086
2MC 1 2MC 2	19140 18860	19000	10.36 10.22	10.29	43830 43400	43620	67750 67790	67780	19.0 20.0	19.5	.0053 .0053	.086 .086
2NC 1 2NC 2	23150 19230	21190	10.15 10.68	10.42	44750 44460	44600	68670 68460	68560	19.5 20.0	19.8	.0055 .0057	.086 .086

TABLE XXXIII (Cont'd)

ROOM TEMPERATURE TENSILE TEST RESULTS OF 2024-T3 ALCLAD SHEET FOR COMPARISON WITH ELEVATED TEMPERATURE RESULTS

2OC 1	20370	22070	10.41	10.42	45220	45170	68980	69010	20.0	20.5	.0061	.086
2OC 2	23770		10.43		45120		69140		21.0		.0061	.086
2PC 1	22520	22000	10.32	10.24	45500	45140	69510	68830	21.0	21.2	.0061	.086
2PC 2	21470		10.17		44780		68100		21.5		.0061	.086
2QC 1	23150	23040	10.31	10.42	45120	45020	68210	68240	20.0	20.0	.0060	.086
2QC 2	22920		10.52		44920		68310		20.0		.0061	.086
2RC 1	22670	22630	10.21	10.19	45400	45440	69100	69130	21.0	20.7	.0060	.086
2RC 2	22500		10.17		45480		69160		20.5		.0058	.086
2SC 1	24010	24010	10.32	10.32	44340	44340	67430	67430	18.0	18.0	.0058	.066
2TC 1	21910	21020	10.44	10.42	44140	44130	67750	67620	20.0	20.0	.0053	.061
2TC 2	20120		10.40		44120		67490		20.0		.0054	.061
2UC 1	22570	22830	10.33	10.39	44340	44210	68650	68270	21.5	21.3	.0054	.069
2UC 2	23100		10.45		44070		67900		21.0		.0051	.069
2VC 1	21240	24400	10.42	9.87	44660	44790	67840	68070	19.0	20.3	.0050	.081
2VC 2	20700		9.31		44910		68290		21.5		.0048	.081
2WC 1	22150	22160	10.47	10.51	44440	44400	68460	68250	20.5	20.3	.0053	.054
2WC 2	22170		10.56		44340		68040		20.0		.0053	.054
2XC 1	26630	23550	11.03	10.83	45070	44780	68250	68280	20.5	20.3	.0051	.054
2XC 2	20460		10.63		44460		68310		20.0		.0049	.054
2YC 1	22110	20480	9.73	9.82	43850	43560	66930	66930	20.0	20.0	.0051	.069
2YC 2	18850		9.91		43260		66930		20.0		.0050	.069
2ZC 1	28880	29690	9.61	9.63	44830	44830	66720	66980	20.5	20.0	.0047	.071
2ZC 2	30490		9.64		44820		67230		19.5		.0049	.071
2AAC 1	27170	28430	9.90	9.97	44720	44470	68170	68310	20.0	20.5	.0049	.071
2AAC 2	29640		10.04		44220		68440		21.0		.0048	.071
2BBC 1	29410	28870	9.87	9.89	45670	45670	69350	69200	21.5	21.8	.0053	.071
2BBC 2	28330		9.91		45670		69040		22.0		.0051	.071
2CCC 1	28950	34120	9.91	9.81	44580	44730	67490	67680	22.0	20.8	.0047	.071
2CCC 2	39290		9.70		44880		67860		19.5		.0049	.071
2DDC 1	18520	16980	9.72	9.91	43920	43880	68210	67900	19.5	19.3	.0050	.069
2DDC 2	15430		10.11		43830		67590		19.0		.0050	.069
2EEC 1	21360	19970	10.03	9.89	43830	42740	68520	67780	22.5	22.0	.0052	.071
2EEC 2	18580		9.75		41640		67030		21.5		.0060	.071
2FFC 1	24720	25000	9.73	9.72	44560	44750	67550	67180	20.0	20.0	.0050	.069
2FFC 2	25290		9.71		44390		66820		20.0		.0050	.069
2GGC 1	19090	17930	9.79	9.97	44360	44200	67870	67950	19.0	19.5	.0054	.058
2GGC 2	16770		10.16		44040		68030		20.0		.0051	.053
2HHC 1	20310	19500	10.07	9.95	43590	43600	68280	68250	20.5	20.3	.0050	.051
2HHC 2	18690		9.84		43610		68220		20.0		.0048	.050
2JJC 1	19110	21210	9.94	9.79	43880	44020	67740	67750	19.5	19.0	.0050	.053
2JJC 2	23310		9.64		44170		67790		20.0		.0048	.054
2KKC 1	14060	15054	10.31	10.24	43236	43240	67313	67316	19.0	18.8	.0050	.052
2KKC 2	16040		10.16		43244		67318		18.5		.0050	.056

TABLE XXXIV

ROOM TEMPERATURE TENSILE TEST RESULTS OF 7075-T6 ALCLAD SHEET
FOR COMPARISON WITH ELEVATED TEMPERATURE RESULTS

Specimen No.	Proportional Limit psi	Average Proportional Limit psi	Modulus of Elasticity 10^6 psi	Average Modulus of Elasticity 10^6 psi	Yield Strength psi	Average Yield Strength psi	Ultimate Strength psi	Average Ultimate Strength psi	Elongation % in 2"	Average Elongation % in 2"	Strain Rate [illegible] in./in./min.	Head Travel in Plastic Range in./min.
7AC 1	31150	36350	9.58	9.36	67050	66380	77710	78010	11.5	11.5	(2)	(2)
7AC 2	41550		9.14		65720		78320		11.5		(2)	(2)
7BC 1	32050	33250	9.45	9.48	[illegible]	66700	[illegible]	77580	12.5	[illegible]	(2)	(2)
7BC 2	34430		9.50		[illegible]		[illegible]		12.5		(2)	(2)
7CC 1	45230	41350	8.92	9.12	66610	66350	76970	76910	12.0	12.8	(2)	(2)
7CC 2	37450		9.31		66080		76850		13.5		(2)	(2)
7DC 1	32950	38590	9.45	9.31	66240	65480	77330	77490	10.5	11.5	(2)	(2)
7DC 2	44210		9.16		65720		77650		12.5		(2)	(2)
7EC 1	42100	36070	9.40	9.60	65940	65830	78550	78240	12.0	12.3	(2)	(2)
7EC 2	30030		9.79		65720		77920		12.5		(2)	(2)
7FC 1	45920	44130	9.37	9.28	67590	67070	78500	78320	13.0	12.8	.0015	(3)
7FC 2	42440		9.18		66550		78130		12.5		.0015	(3)
7GC 1	39250	40270	9.31	9.40	66820	66630	77880	77890	12.0	12.7	.0039	(3)
7GC 2	41290		9.49		66450		77900		13.5		.0039	(3)
7HC 1	42440	41890	8.74	9.04	66880	66450	78130	78000	13.0	12.7	.0031	(3)
7HC 2	41340		9.34		66020		77890		12.5		.0033	(3)
7IC 1	42520	44290	9.32	9.23	65890	65760	77850	77230	12.0	12.0	.0040	(3)
7IC 2	46060		9.14		65540		76610		12.0		.0040	(3)
7JC 1	40320	41290	9.29	9.29	67250	67250	77350	77850	12.0	12.3	.0032	.086
7JC 2	41770		9.29		67250		77850		12.5		.0032	.085
7KC 1	37100	35650	9.20	9.32	67900	67420	78230	78350	12.5	12.3	.0038	.086
7KC 2	34200		9.44		66940		78500		12.0		.0042	.086
7LC 1	34790	32610	9.42	9.48	66500	65610	78320	78320	12.0	11.8	.0041	.086
7LC 2	30420		9.54		64720		78320		11.5		.0042	.086
7MC 1	30840	29870	9.48	9.56	65320	64960	77440	77350	12.0	11.8	.0040	.086
7MC 2	28900		9.65		64610q		77270		11.5		.0039	.086
7NC 1	33930	35920	9.40	9.27	66560	66340	77600	77430	11.0	11.3	.0027	.110
7NC 2	37900		9.15		66130		77260		11.5		.0026	.110

TABLE XXXIV (Cont'd)

ROOM TEMPERATURE TENSILE TEST RESULTS OF 7075-T6 ALCLAD SHEET FOR COMPARISON WITH ELEVATED TEMPERATURE RESULTS

7OC 1	32150	30990	9.37	9.38	65110	65290	76530	76890	11.5	12.0	.0026	.110
7OC 2	29840		9.37		65480		77260		12.5		.0026	.110
7PC 1	34460	33710	9.31	9.33	67470	67490	78690	78740	13.0	13.0	.0053	.086
7PC 2	32960		9.36		67520		78780		13.0		.0053	.086
7QC 1	31920	30810	9.24	9.26	66940	66990	77850	77890	12.5	12.3	.0053	.081
7QC 2	29710		9.29		67040		77920		12.0		.0052	.081
7RC 1	45950	45170	9.41	9.47	68280	68060	78960	78740	13.0	13.2	.0060	.081
7RC 2	44390		9.53		67850		78520		13.5		.0060	.081
7SC 1	34680	37440	9.76	9.53	67420	68120	79520	79470	14.0	14.2	.0058	.081
7SC 2	40190		9.30		68810		79420		14.5		.0063	.081
7TC 1	41690	44800	8.93	8.80	68210	68450	78430	78590	14.5	14.5	.0063	.081
7TC 2	47920		8.67		68690		78750		14.5		.0061	.081
7UC 1	46840	46760	9.04	9.03	69400	69320	79500	79500	12.5	12.5	.0062	.086
7UC 2	46690		9.03		69240		79500		12.5		.0057	.086
7VC 1	47100	46700	9.13	9.08	68550	68490	78870	78940	11.5	12.2	.0058	.086
7VC 2	46310		9.02		68430		79010		13.0		.0059	.086
7WC 1	42770	44550	9.15	9.05	68010	68110	78620	78610	14.0	13.5	.0061	.067
7WC 2	46330		8.95		68210		78590		13.0		10061	.067
7XC 1	48330	48680	9.20	9.07	68390	68140	78710	78650	13.0	13.3	.0080	.061
7XC 2	49030		8.94		67880		78590		13.5		.0080	.061
7YC 1	45830	46060	9.03	9.00	68170	68170	78940	78860	13.5	13.3	.0053	.081
7YC 2	46300		8.96		68170		78780		13.0		.0050	.081
7ZC 1	46310	46240	9.14	8.97	68110	68370	78850	78880	12.0	12.3	.0048	.067
7ZC 2	46170		8.80		68630		78910		12.5		.0048	.067
7AAC1	45940	45860	9.10	9.18	68750	68590	79530	79450	12.5	12.8	.0048	.067
7AAC2	45780		9.27		68440		79380		13.0		.0046	.067
7BBC1	46760	47260	9.29	9.22	69260	68790	79770	79870	13.0	12.8	.0046	.067
7BBC2	47760		9.15		68330		79970		12.5		.0048	.067
7CCC1	45990	46550	9.16	9.06	68590	68560	79330	79480	13.0	12.5	.0048	.069
7CCC2	47120		8.97		68530		79230		12.0		.0048	.069
7DDC1	29750	30800	9.07	9.04	66300	66430	77690	77780	11.5	11.5	.0054	.069
7DDC2	31850		9.00		66560		77870		11.5		.0051	.069
7EEC1	41010	40180	9.19	9.40	68450	68320	78550	77640	12.5	12.5	.0051	.069
7EEC2	39340		9.61		68200		76740		12.5		.0051	.069
7FFC1	37090	36930	8.82	8.78	64620	65010	75540	75930	12.5	12.5	.0051	.069
7FFC2	36770		8.74		65390		76310		12.5		.0051	.069
7GGC1	34640	36210	9.06	8.94	66930	66670	77120	76870	12.5	13.0	.0051	.069
7GGC2	37780		8.82		66410		76620		13.5		.0050	.069

TABLE XXXIV (Cont'd)

ROOM TEMPERATURE TENSILE TEST RESULTS OF 7075-T6 ALCLAD SHEET FOR COMPARISON WITH ELEVATED TEMPERATURE RESULTS

7HHC1	38000	36470	9.01	9.08	65420	65470	77570	77290	13.5	13.2	.0050	.069
7HHC2	34940		9.16		65530		77020		13.0		.0050	.069
7IIC1	33460	30270	8.88	9.00	64590	64340	75780	75660	11.5	13.3	.0054	.069
7IIC2	27060		9.13		64090		75540		15.0		.0054	.069
7JJC1	39260	40290	9.13	9.16	68590	68850	79970	80260	12.0	12.7	.0050	.054
7JJC2	41320		9.19		69130		80550		13.5		.0050	.054
7KKC1	16990	18400	10.00	10.04	66340	66660	79940	80010	12.5	12.0	.0058	.052
7KKC2	19810		10.09		66990		80090		11.5		.0058	.052
7LLC1	47760	47680	8.97	8.90	71080	71080	79230	79070	15.0	14.8	.0056	.072
7LLC2	47600		8.84		71080		78910		14.5		.0060	.078

1. Autographic load strain curve exhibited a continuous curve. Primary modulus, secondary modulus, or proportional limit could not be determined.

2. Strain and head travel rates were not determined on the first tests performed. From standard laboratory practice, it is estimated that these tests were performed at .004 in./in./min. strain rate within elastic region and .04 in./min. head travel from yield to fracture.

3. Head travel rate adjusting dial on tensile machine was out of calibration during these tests.